Nettie Yearian

Ruth Yearian

[illegible]

sinuses
of frontal, maxillary
Ethmoid Sphenoid
Extern [illegible] of Hyp[illegible]

Systole

Cu
Colestirol — stagnation
Bile pigments

weighs 120 lbs

~~crazy~~ VI

1 cu cm = 1000 cu mm
1 litre = 1000 cu cm
1 " = 1000000 cu mm
3 " = 3000000 "

5 000000 × 3 000000 =
15 000000000000 red blood cells

7,500
3000000
22,500,000,000 white blood cells

11-12 45
7-930

Lister - contributations of the antiseptic principle in the practice of surgery - carbolic acid 1865

Pasteur - pasteurgation @ a temp of 55°-60° of all perishable foods.
Vaccine against anthrax in 188
Vaccine " hydrophobia 18

Noguchi - dis. the parasite causing yellow fever 1920

Schaudinn - dis. the spirochete pallida of syph. 1905

Semmelweiss - antiseptic treatm in deliveries.

Shiga Kiyoshi - dis. the B. dysente

Eberth - dis. cause of typhoid F.

Ehrlich - Fuchsin stain for T.B.
606 - salvarsan in treat of syph.

Neisser - dis of gonorrhea 1879

Oliver Wendell Holmes - read paper to the Boston Medical Society for med. imprisonment of his paper on Contagion of Puerperal Fever - aseptic condition + use of calcium chloride.

ANATOMY AND PHYSIOLOGY FOR NURSES

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TEXT-BOOK

OF

ANATOMY AND PHYSIOLOGY FOR NURSES

BY

DIANA CLIFFORD KIMBER

GRADUATE OF BELLEVUE TRAINING SCHOOL; FORMERLY ASSISTANT SUPERINTENDENT NEW YORK CITY TRAINING SCHOOL FOR NURSES, BLACKWELLS ISLAND, N.Y.; FORMERLY ASSISTANT SUPERINTENDENT ILLINOIS TRAINING SCHOOL, CHICAGO, ILL.

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PREFACE TO THE FIFTH EDITION

It is now a quarter of a century since the appearance of the first edition of this text-book which grew out of Miss Kimber's own experience in the classroom and which has always represented the work of a nurse for nurses. Only one who has worked in nurse-training schools can appreciate the peculiar disadvantages under which the nurse instructor works, because of the varying standards of admission, hours of duty, inadequate equipment, meagre libraries, etc. We believe that in nursing, as in medicine, our most helpful books must be produced within the profession because one who has travelled each step of the way, as pupil, instructor, and administrator, has a more complete understanding of the needs of nurses than can possibly be gained in a less intimate participation in the work.

In this revision the basic importance of physiology, in the training and education of the nurse, has been constantly borne in mind. This subject must form the groundwork for the study of hygiene, dietetics, materia medica, and all pathological conditions, as well as for the intelligent practice of nursing methods. Enough anatomy is given to make the physiology intelligible, for we must understand the plan or organization of the body before we can appreciate its functioning.

The study of physics and chemistry should precede that of anatomy and physiology. When this is not possible, the best compromise is to have chemistry a parallel course. Physiology, being a constantly growing subject, we cannot expect to teach final truth. If this book raises many more questions than it answers, it will have served its purpose, because to arouse interest, stimulate curiosity and inquiry are the main objects of teaching.

In a cultivation of the scientific habit of thought, the laboratory method is invaluable. We do not expect the student to make

new discoveries, but she can be shown how the discoveries of others have been brought about.

Free use should be made of the reference library and this should be adequate and up-to-date.

Blackboard drawings are invaluable. Models and charts are useful, but nothing takes the place of the actual specimen which can be handled and dissected.

The aim of this book is to describe in as simple a manner as possible the phenomena of life, and the principal conclusions which have been reached as to their interdependence and causes.

The gratifying approval which previous editions have received has made it seem unwise to attempt any change in the order of the chapters. This seems of minor importance since every teacher will wish to follow her own method in teaching, taking the systems in such order as seems to her most reasonable.

I have had the advantage, as formerly, of the help and advice of many fellow-workers in the training schools, and to them I extend my thanks. I am specially indebted to Caroline E. Stackpole, M.A., Instructor in Biology, Teachers College, for reading and criticising my manuscript; to Robert M. Lovett, M.D., of Boston, for valuable assistance with the chapter on muscles; to Helen L. Redfern, R.N., for assistance with the illustrations, and to Mabelle S. Welsh, R.N., for assistance in proof-reading and for making the index.

I am also indebted to the authors whose works I have consulted, and to the various publishers who have granted me permission to use illustrations from their books.

C. E. G.

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ANATOMY AND PHYSIOLOGY
FOR NURSES

CHAPTER I

EXPLANATIONS AND DEFINITIONS OF SOME CHEMICAL AND PHYSICAL TERMS

An intelligent discussion of the various functions of the human body cannot be given without some elementary considerations in the field of chemistry and its intimately related science of physics. Probably the briefest method for presenting the essential points is in the way of definitions with accompanying illustrations, and explanations where necessary.

THE PHYSICAL SCIENCES

1. **Physics** deals with mechanics, heat, light, sound, and electricity, and their relations to matter.

2. **Chemistry** deals with change in the composition of matter, the energy change involved therein, and the principles controlling chemical change.

MATTER

1. **Defined.** — *Matter* is usually defined as anything that occupies space, and possesses weight, as wood, air, water.

2. **Forms in which matter exists.**

Elements. — An element is a substance which cannot be separated into more simple substances by any means known to science at present. Elements are supposed to be made up of *atoms* which are alike for the same element and cannot be divided.

There are about eighty of these elements, less than half of which are well known. Some of the most common are carbon, iron, sulphur, mercury, and oxygen.

Compounds. — A compound is a substance which can be separated into simpler substances. Compounds are supposed to be made up of *molecules* which are composed of groups of *atoms*. Molecules are alike for the same compound and can be divided,

giving elements or simpler compounds. For example, water is composed of hydrogen and oxygen, each molecule having in it two hydrogen atoms and one oxygen atom (H_2O); when separated, water gives the two elements hydrogen and oxygen. Again, sugar is composed of hydrogen, carbon, and oxygen, each molecule having in it twelve atoms of carbon, twenty-two atoms of hydrogen, and eleven atoms of oxygen ($C_{12}H_{22}O_{11}$); when separated it gives several compounds with simpler molecules, as carbon dioxide (CO_2), water (H_2O), methane (CH_4), etc.

Mixtures. — A mixture can be made up of either or both elements and compounds. These can often be separated by simple physical means, as filtration or evaporation. Milk is a mixture of several compounds, — water, cream, proteins, sugar, and salts. The cream can be separated by allowing the milk to stand, when it will rise to the top, and can be skimmed off. Salt solution is a mixture of the compounds, salt and water. They can be separated by evaporating the water. Air is a mixture of compounds and elements, carbon dioxide (compound), nitrogen and oxygen (elements). They cannot be separated by any simple means.

3. Matter undergoes changes.

Physical change. — When matter has been subjected to a change which does not affect the composition of the matter, the change is said to be a physical one only. The following are given by way of illustration: —

Water can solidify (freeze) or it can vaporize; whether it exists in the state of a solid, a liquid, or a gas, depends upon the temperature, but the composition in all these *states* is identical. Sugar melts, but the solid sugar and the liquid sugar are exactly the same in composition; the change is only one in *physical state*.

Other physical changes besides change in *physical state* are, change in *size*, *position*, *magnetic* or *electric* condition, and change in *temperature*.

Chemical change. — When matter undergoes a change in composition, it is said to have undergone a chemical change. The following are illustrations: when an electric current is passed through water, the water is separated into two distinct substances, hydrogen and oxygen. In this case we start with a single compound (water) of definite composition, and as a result of the change, obtain two different substances (oxygen and hydrogen).

Again, in a bar of iron there is nothing but the element iron, but if it is left exposed to the air, it is converted into a red solid which has iron and oxygen in it, the iron having combined with some of the oxygen from the air. The iron and the iron rust are evidently different in composition.

ELEMENTS FOUND IN THE BODY

The elements found in the body are: —

Carbon,	13.5	(C)	form 97 per cent of total weight of body.
Hydrogen,	9.1	(H)	
Nitrogen,	2.5	(N)	
Oxygen,	72.0	(O)	
Sulphur,		(S)	
Phosphorus,		(P)	
Fluorine,		(F)	
Chlorine,		(Cl)	
Iodine,		(I)	
Silicon,		(Si)	
Sodium,		(Na)	
Potassium,		(K)	
Calcium,		(Ca)	
Magnesium,		(Mg)	
Lithium,		(Li)	
Iron,		(Fe)	
Manganese,		(Mn)	
Copper,		(Cu)	
Lead,		(Pb)	

These elements are not, of course, found uncombined in the body, but rather combined, usually in the form of rather complex compounds. *Protoplasm*, for instance, is a compound of carbon, hydrogen, nitrogen, oxygen, and phosphorus.

ORGANIC AND INORGANIC COMPOUNDS

The distinction between organic and inorganic compounds dates back to an early period, when there was a belief that certain compounds of carbon found in living organisms could only be built up through the agency of a vital force possessed by the organism, which prevented their being synthesized in the chemical laboratory. In distinguishing such they were spoken of as organic compounds. However, when urea, one of these substances, was prepared in

the laboratory, this theory was abandoned, but the distinctive terms *organic* and *inorganic* persisted. Under the present classification organic compounds are compounds that contain carbon.

Because of the fact that there are numerous carbon compounds and also because many of these can be grouped into classes with well-defined characteristics, the study of the carbon compounds has become a separate phase of the general study of chemistry and is called *organic chemistry.*

SOME CHEMICAL TERMS

Atom. — An atom is the smallest part into which an element can be divided. Atoms are alike for the same element, but different for different elements.

Molecule. — A molecule is a group of atoms in chemical combination. Compounds are made up of multitudes of molecules, all of which are alike for the same compound.

Chemical formula. — A chemical formula is a simple means for representing the composition of the molecule. *Symbols* are made use of to represent the elements and small subscript figures to represent the number of atoms of the respective elements. For example, the formula for the sulphuric acid molecule (H_2SO_4) shows it to be made up of two atoms of hydrogen, one atom of sulphur, and four atoms of oxygen; the formula for the sodium chloride molecule (NaCl) shows it to be made up of one atom of sodium and one of chlorine.

Chemical equation. — A chemical equation is a simple means for representing the matter change that takes place in a chemical action. When carbon burns it combines with oxygen to form carbon dioxide. The equation that expresses this,

$$C + O_2 \rightarrow CO_2,$$

tells that during the process of combination, one atom of carbon combines with one molecule of oxygen (composed of two atoms) to give one molecule of carbon dioxide. In the action of sodium hydroxide with hydrochloric acid, water and sodium chloride are formed. The equation to represent this,

$$NaOH + HCl \rightarrow H_2O + NaCl,$$

shows that one molecule of sodium hydroxide reacts with one molecule of hydrochloric acid to give one molecule of water and one molecule of sodium chloride.

Oxide. — An oxide is a compound in which another element is in combination with oxygen, as water (H_2O), carbon dioxide (CO_2), sulphur dioxide (SO_2), and iron oxide (Fe_2O_3).

Acid oxide. — An acid oxide (or acid anhydride) is an oxide of a non-metal which in combination with water will form an acid, as carbon dioxide and sulphur dioxide, shown in the following: —

$$CO_2 + H_2O \rightarrow H_2CO_3 \text{ (carbonic acid)},$$
$$SO_3 + H_2O \rightarrow H_2SO_4 \text{ (sulphuric acid)}.$$

Basic oxide. — A basic oxide (or basic anhydride) is an oxide of a metal which in combination with water will give a base, as calcium oxide (CaO) and sodium oxide (Na_2O), shown in the following: —

$$CaO + H_2O \rightarrow Ca(OH)_2 \text{ (calcium hydroxide)},$$
$$Na_2O + H_2O \rightarrow 2\ NaOH \text{ (sodium hydroxide)}.$$

Ion. — An ion is an atom or group of atoms charged with electricity.

Acid. — An acid is a substance, containing hydrogen and an acid radical, which dissolved in water or other dissociating liquid produces hydrogen ions. The acid radical must contain a non-metal and may contain oxygen. Examples are hydrochloric acid (HCl), sulphuric acid (H_2SO_4), carbonic acid (H_2CO_3), hydrobromic acid (HBr), nitric acid (HNO_3).

Base. — A base is a substance which contains a metal and the hydroxyl (OH) radical. Examples are sodium hydroxide ($NaOH$) and calcium hydroxide ($Ca(OH)_2$). One exception to this is ammonium hydroxide (NH_4OH), which contains the ammonium radical (NH_4) instead of a metal.

The *alkalies* are the bases of sodium, potassium, and ammonium; they give very strong basic action.

Both acids and bases give distinctive characteristic actions.

Salt. — A salt is a substance containing the metal from a base and the acid radical from an acid. Salts may be obtained by the neutralization of an acid by a base, the characteristic hydrogen of the acid combining with the characteristic hydroxyl of the base to form water, leaving the salt as shown in the following: —

$$\text{Base} + \text{Acid} \rightarrow \text{Water} + \text{Salt}$$
$$NaOH + HCl \rightarrow H_2O + NaCl \text{ (sodium chloride)},$$
$$Ca(OH)_2 + H_2SO_4 \rightarrow 2H_2O + CaSO_4 \text{ (calcium sulphate)}.$$

SOME GENERAL CHEMICAL ACTIONS

Oxidation. — Oxidation is the process in which the element oxygen combines chemically with another substance, heat being evolved in the process. The heat evolved may not be perceptible unless the oxidation takes place rapidly, as in the burning of gas, wood, coal, etc. If the substance combines slowly with oxygen, heat may be imperceptible; for example, iron allowed to lie in moist air is covered with rust due to the union of the iron and oxygen. Also in our bodies some of the carbon in the cells unites with oxygen, and thus the temperature of the body is kept up. It is for this reason that oxygen must be taken into the body, which is accomplished by the act of breathing. (See page 258.)

Neutralization. — Neutralization is the process that takes place in the action of an acid with a base. Water and a salt are the products of the reaction. (See **Salt**.)

Hydrolysis. — Hydrolysis can be defined as the chemical change that takes place when a compound in its action with water splits into two other compounds, fixing the elements of water in the process. The action of water with some salts, also the formation of glucose and fructose from cane sugar, may be given as examples, as represented in the following reaction equations: —

$$\underset{\text{(Sodium carbonate)}}{Na_2CO_3} + 2\,H_2O \rightarrow \underset{\text{(Sodium hydroxide)}}{2\,NaOH} + \underset{\text{(Carbonic acid)}}{H_2CO_3},$$

$$\underset{\text{(Cane sugar)}}{C_{12}H_{22}O_{11}} + H_2O \rightarrow \underset{\text{(Fructose)}}{C_6H_{12}O_6} + \underset{\text{(Glucose)}}{C_6H_{12}O_6}.$$

Hydration. — Hydration is the process by which water enters into direct combination with another compound to form a single compound which is called a *hydrate*. As examples might be given, sulphuric acid (H_2SO_4) as a hydrate of sulphur trioxide (SO_3), calcium hydroxide ($Ca(OH)_2$) as a hydrate of calcium oxide (CaO), and crystalline copper sulphate ($CuSO_4 . 5\,H_2O$) as a hydrate of anhydrous copper sulphate ($CuSO_4$). The formation of these hydrates in the process of hydration is represented in the following: —

$$\begin{array}{lcl}
\text{Anhydrous substances} & & \text{Hydrates} \\
SO_3 + H_2O & \rightleftarrows & H_2SO_4 \\
CaO + H_2O & \rightleftarrows & Ca(OH)_2 \\
CuSO_4 + 5\,H_2O & \leftrightarrows & CuSO_4 . 5\,H_2O.
\end{array}$$

The reverse process by which a compound is split up into water and an anhydrous compound is called *dehydration*. This process is represented in the equations by the reverse arrows.

Catalysis. — Catalysis is the process by means of which the time reaction of chemical changes can be varied by substances known as catalyzers. Manganese dioxide is a classical example of a catalyzer. For example, to make potassium chlorate yield up its oxygen it is necessary to raise its temperature to about 360 degrees. If, however, a little manganese dioxide is added, the oxygen is released at a much lower temperature, vice 200 degrees. There are many catalyzers that control chemical reactions in the body.

ENERGY

Energy is ordinarily defined as the power of doing work. Examples of various types of energy are: mechanical energy, heat energy, electrical energy, and chemical energy. These can be transformed from one form to another. To illustrate: (1) electrical energy can be converted into energy of motion, as evidenced in the motor; (2) electrical energy can be converted into heat energy, as in the electric stove; (3) mechanical energy of motion can be converted into electrical energy, as in the dynamo; also, (4) chemical energy can be transformed into heat energy, as is true in the oxidation of food in our bodies.

SOME PHYSICAL TERMS

Specific gravity. — By specific gravity is meant the comparison between the weight of a substance and the weight of an equal volume of some other substance taken as a standard. The standards usually referred to are air for gases, and water for liquids and solids. For instance, the specific gravity (sp. gr.) of carbon dioxide (air standard) is 1.5, meaning that it is 1.5 times as heavy as an equal volume of air. Again the specific gravity of mercury (water standard) is 13.6, meaning that mercury is 13.6 times as heavy as an equal volume of water. The specific gravity of solutions, as a salt solution, will necessarily vary with the concentration.

Diffusion. — This term in its ordinary use has to do with the tendency of two liquids or two gases of different densities to mix uniformly. Diffusion can take place either when the substances

are simply superimposed, or when they are separated by a membrane. The following illustrations may help to make this clear: —

1. When the gases or liquids are not separated by a membrane.

(*a*) If a bottle of hydrogen is inverted over a bottle of chlorine gas, the lighter hydrogen molecules will move down among the chlorine molecules, while the heavier chlorine molecules will move up to mix with the hydrogen molecules, so that the two will eventually be mixed uniformly.

(*b*) If a layer of water is placed carefully over a layer of sulphuric acid, in such a way that the two do not mix, two distinct layers will be formed with the heavier sulphuric acid at the bottom. The acid molecules will begin to move up and mix with the water molecules, while the water molecules will move down to mix with the sulphuric acid molecules. The action is much slower than with the gases.

2. When the gases or liquids are separated by certain membranes.

(*c*) In the illustration given in (*a*) if a membrane, permeable to gases, be stretched over the mouth of the bottle, the gases will mix evenly through it. Also, if a membranous sac of carbon dioxide is placed in a vessel containing oxygen, the two gases will diffuse through the membrane, until the mixture of gases inside and outside is uniform.

(*d*) When a bladder of alcohol is immersed in water, the two liquids will diffuse through the membrane; the water diffusing more rapidly than the alcohol, the bladder will become distended.

This subject of diffusion is an important one as the activities which make life possible for each cell are dependent upon it. (See **Respiration**, **Circulation**, **Metabolism**, and **Excretion**. Pages 258, 184, 334, 362.)

The explanation of the process is found in the suppositions of the *kinetic theory* that: —

1. There are spaces between the molecules making up all fluid bodies.

2. Molecules are in rapid motion in straight lines, the motion of molecules of gases being much more rapid and unrestrained than in the case of molecules of liquids.

For an understanding of the two forms of diffusion through membranes called **osmosis** and **dialysis**, a few definitions are necessary.

1. **Permeable membranes.** — Permeable membranes allow the passage not only of water molecules but of substances in solution, *i.e.*, salt molecules. If a tumbler be completely divided vertically by a permeable membrane, and two ounces of salt solution placed on one side and four ounces of water placed on the other, it will be found that the water first passes over to the side containing salt solution; later the salt molecules will pass over to the water, so that eventually the quantity of water and salt will be equal on both sides of the membrane. In other words there will be three ounces of salt solution on each side of the membrane instead of two ounces of salt solution on one side and four ounces of water on the other, which was the condition we started with.

2. **Semipermeable membranes.** — Semipermeable membranes allow the passage of water molecules but not substances in solution. If our glass had been divided by a semipermeable membrane, the water molecules could have passed through, but *not* the salt. Most of the membranes we have in the body are approximately semipermeable, *i.e.*, they allow water molecules to pass through readily, and molecules of substances in solution less readily. In such cases the stream of water is to the side of the dissolved substance, but at the same time the molecules of this substance pass to some extent to the other side.

3. **Osmotic pressure.** — In the experiment just described (under **Permeable Membranes**) it was said that the water passed over to the side of the glass containing salt solution. The old expression was that the salt attracted the water, but in the newer theories the same fact is expressed by saying that the salt in solution exerts a certain *osmotic pressure*, in consequence of which more water flows from the water side to the side of the salt solution than in the reverse direction. As a matter of experiment it is found that the osmotic pressure varies with the amount of the substance in solution, or in other words, depends upon the concentration of the solution.

4. **Isotonic, Hypertonic, and Hypotonic.** — These terms are used to express degrees of osmotic pressure or differences in concentration. For instance, normal salt solution is used to replace blood lost by hemorrhage, because the osmotic pressure of normal salt solution is equal to that of blood, hence it is *isotonic* or *isomotic* to the blood, *i.e.*, contains the same amount of salt as the blood.

If the solution contained a higher percentage of salt than the blood, it would be *hypertonic*, if lower *hypotonic*.

5. **Solution.** — When a substance disappears in a liquid in such a way as to thoroughly mix with it and be lost to sight as an individual body, the resulting liquid is called a solution. It therefore requires two substances to make a solution, one the liquid or *solvent*, and the other the substance dissolved or *solute*.

6. **Osmosis.** — Osmosis is the passage of solvent molecules through a membrane.

7. **Dialysis.** — Dialysis is the passage of solute molecules through a membrane.

8. **Emulsion.** — An emulsion is a mixture of two immiscible fluids, where one is scattered through the other in the form of finely divided globules.

UNIT FOR MEASURING HEAT

Inasmuch as heat is a form of energy, it is not as simple an undertaking to speak of it in comparative terms as in the case of matter. It is easy for one to visualize five quarts of milk as five times a certain volume that has been taken as a standard and called one quart. So it is also with weights and distances, and the measurement of weights, distances, and volumes is a necessary part of our experience. It is quite as urgent that there should be a basis for the comparison of energy values as well as for matter values, else the coal dealer could not place the value of his coal on a basis of its heat-producing qualities, nor could the dietitian plan meals on a basis of the ultimate energy-producing qualities to the individual. We are only conscious of energy as a result of the effect it produces, consequently, if it is to be measured, it must be on this basis. In physiology the unit used for measuring heat is the calorie.

Calorie. — The calorie (Cal.) is the amount of heat that is necessary to raise 1000 grams of water through 1° C. Occasionally a small calorie is used. This small calorie is the amount of heat that is necessary to raise one gram of water through 1° C. It is, therefore, only $\frac{1}{1000}$ as large as the calorie.

CHAPTER II

DEFINITIONS. — CAVITIES OF THE HUMAN BODY

DEFINITIONS

Before taking up the study of anatomy and physiology in detail, it is well to consider the definitions of these terms as follows: —

Anatomy refers to the structure of an organism.

Physiology refers to the functions of an organism.

Anatomy teaches us what organs a plant or animal has, and how they are arranged with reference to one another. Physiology teaches us the uses to which these organs are put. Anatomy shows what an organ is; physiology shows what an organ does. Anatomy may be, and usually is, studied upon the dead creature; physiology can be studied only upon the living creature.

The anatomical position. — In describing the body, anatomists always consider it as being in the erect position, with the face toward the observer, the arms hanging at the sides, and the palms of the hands turned forward.

Surfaces of the body. — When the body is in the anatomical position, the front, or surface facing the observer, is named the *ventral* surface. (See Fig. 1.) The back, or surface directed away from the observer, is named the *dorsal* surface. (See Fig. 2.)

The median line. — This refers to an imaginary line drawn through the middle of the body, from the top of the head to the middle of the floor between the feet. The parts nearest this line are described as *medial,* the parts farthest from this line are described as *lateral.*

Internal and external. — These terms are used to designate within and without the body itself, also within and without the body cavities.

Proximal and distal. — Proximal is used to describe a position near the head or source of any part. Distal is used to describe a

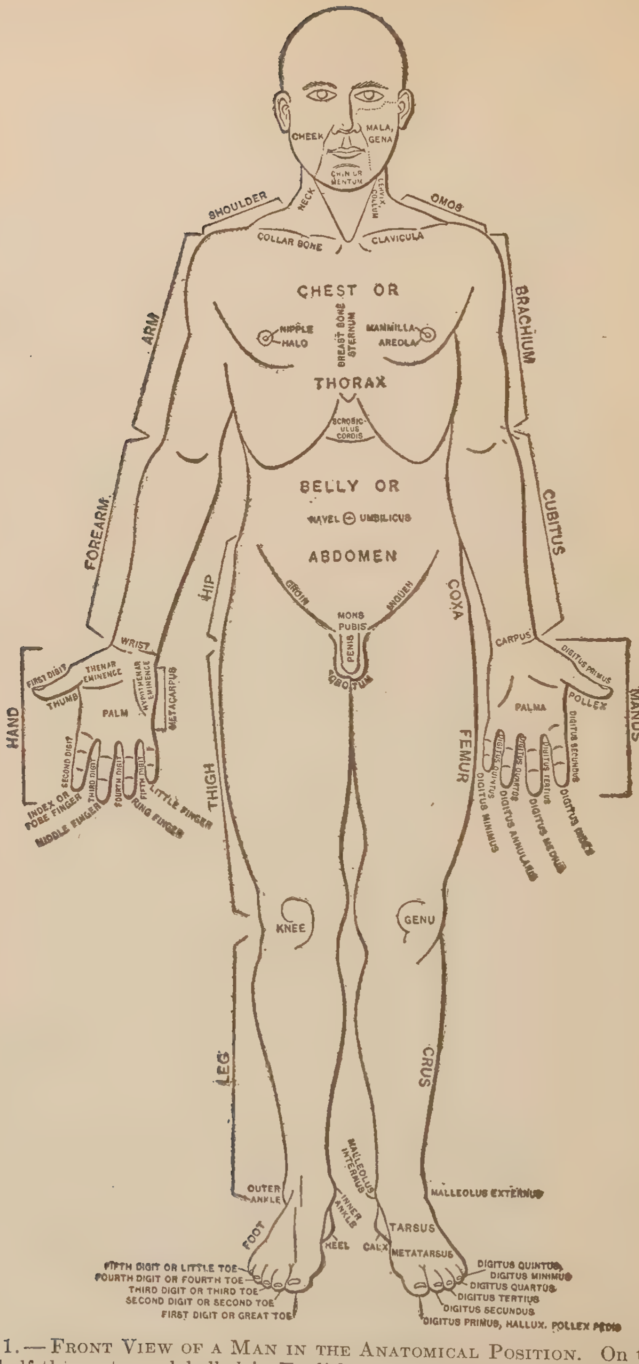


FIG. 1.—FRONT VIEW OF A MAN IN THE ANATOMICAL POSITION. On the right lateral half the parts are labelled in English, on the left in Latin. The right upper limb is drawn away from the trunk in order to show the arm more fully than is possible when it hangs perpendicularly. (Gerrish.)

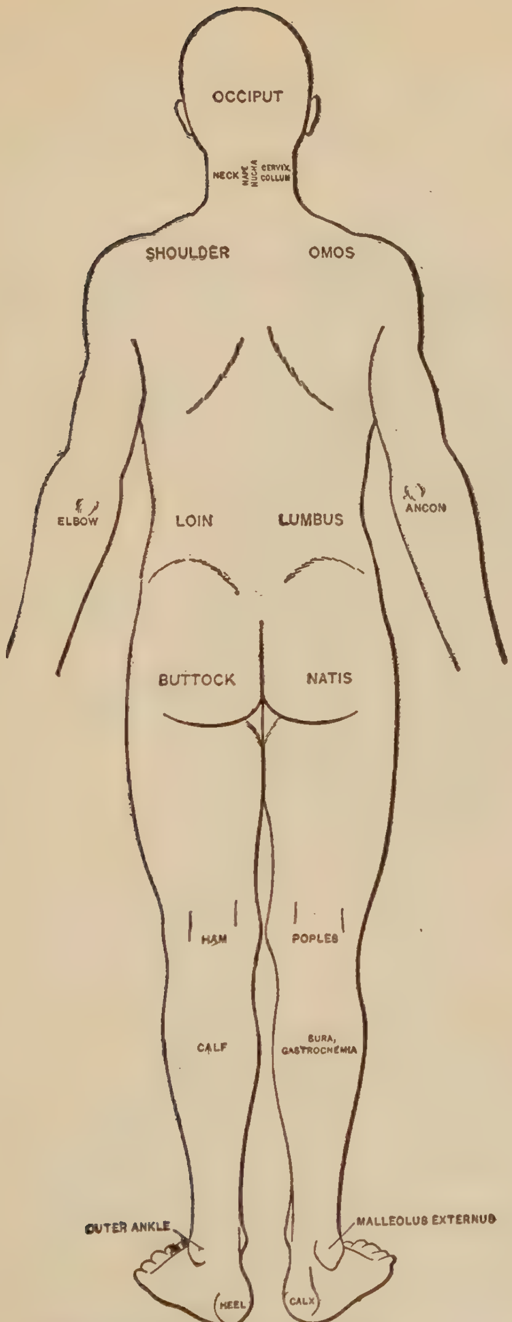


FIG. 2.—BACK VIEW OF A MAN. On the left lateral half the names of the parts are given in English, on the right in Latin. (Gerrish.)

position distant, or farthest away from the head or source of any part.

Periphery. — This term is used to describe the circumference of a circle, hence in anatomy it means the outside or surface of a body or an organ.

THE HUMAN BODY

It is necessary to have the clearest possible conception of the main divisions and the positions of the different parts of the body,

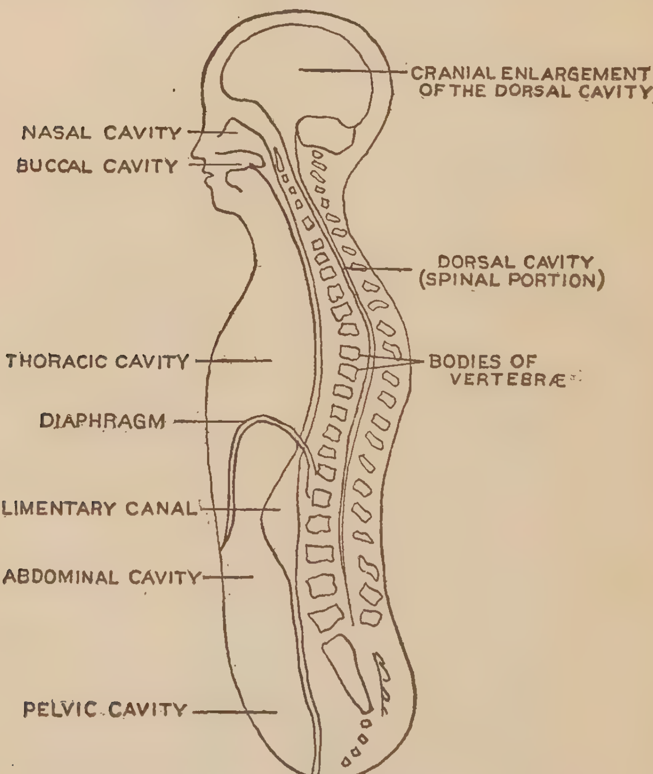


FIG. 3. — DIAGRAMMATIC LONGITUDINAL SECTION OF THE TRUNK AND HEAD. The alimentary canal is represented running through the whole length of the ventral cavity.

and we shall therefore outline the structure of the body as a whole. It is readily seen that the human body is separable into **trunk**, **head**, and **limbs**; the **trunk** and **head** are cavities,[1] and contain

[1] In this connection it is important to emphasize that so-called body cavities are only potential cavities which do not become real ones unless their contents are

the internal organs or viscera,[1] while the **limbs** are solid, contain no viscera, and are merely appendages of the trunk.

Cavities of the body. — The trunk and head contain two main cavities, and looking at the body from the outside we should naturally imagine that these two cavities were the cavity of the head and the cavity of the trunk, respectively. If, however, we divide the trunk and head lengthwise into two halves, by cutting them through the middle line from before backwards, we find the **trunk** and **head** are divided by the bones of the spine into dorsal and ventral cavities, and not into upper and lower. (See Fig. 3.)

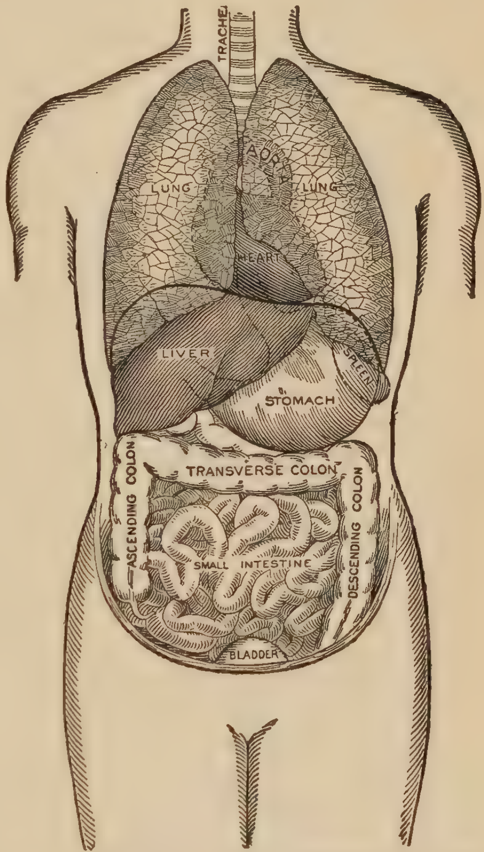


FIG. 4. — POSITION OF THE THORACIC AND ABDOMINAL ORGANS (FRONT VIEW). (MORROW.)

1. **Dorsal cavity.** — The dorsal or back cavity is a complete bony cavity, and is formed by the bones of the skull, and the vertebræ (bones of the spine). It may be subdivided into: —

a. The *cranial cavity.* — This cavity contains the brain.

b. The *spinal canal.* — This canal contains the spinal cord, which is continuous with the brain.

2. **Ventral cavities.** — The ventral or front cavities are not com-

removed. In life they are completely filled by the organs plus a small quantity of fluid.

[1] *Viscera* is the plural of the Latin word viscus, which means an organ; hence viscera are organs contained within the body cavities. Example: heart, stomach, etc. Each of these may be called a *viscus.*

plete bony cavities, part of their walls being formed of muscular and other tissue.

a. Orbital cavity. — The orbital cavity contains the eye, the optic nerve, the muscles of the eyeball, and the lacrimal apparatus.

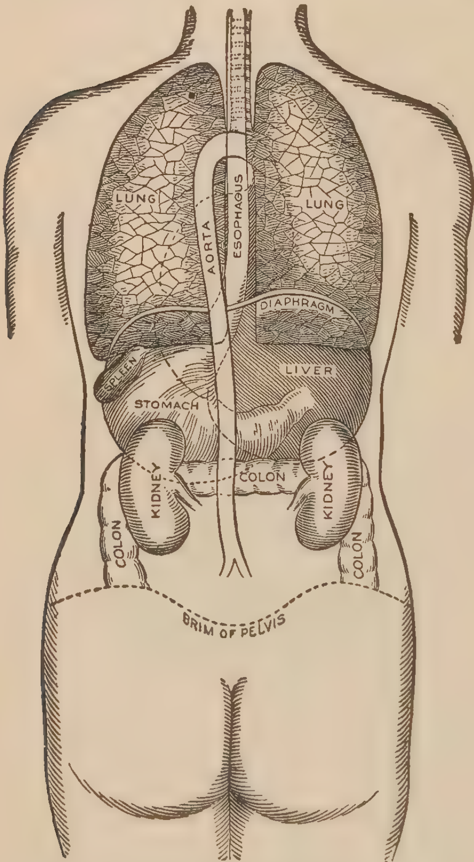


FIG. 5. — POSITION OF THE THORACIC AND ABDOMINAL ORGANS (REAR VIEW). (Morrow.)

b. Nasal cavity. — The nasal cavity is filled in with the structures forming the nose.

c. Buccal cavity. — The buccal cavity or mouth contains the tongue, teeth, and salivary glands.

d. Thoracic cavity. — The thoracic cavity, or chest, contains the trachea or windpipe, the lungs, œsophagus or gullet, heart, and the great vessels springing from, and entering into, the heart.

Diaphragm. — The diaphragm is a dome-shaped membranous and muscular partition between the thoracic and abdominal cavities.

e. Abdominal cavity. — The abdominal cavity contains the stomach, liver, gall-bladder, pancreas, spleen, small and large intestines.

f. Pelvic cavity. — The pelvic cavity is that portion of the abdomen lying below an imaginary line drawn across the prominent crests of the hip bones. It is more completely bounded by bony walls than the rest of the abdominal cavity. It is divided by a narrowed bony ring into the large (false), and small (true) pelvis.

(See Fig. 59.) The small or true pelvis contains the bladder, rectum, and some of the generative organs.

The **limbs**, or **extremities**, upper and lower, are in pairs, and bear a rough resemblance to one another, the shape of the bones, and the disposition of the muscles in the thigh and arm, leg and forearm, ankle and wrist, foot and hand, being very similar. There is, however, a marked difference between the mobility of the upper and the lower limbs. The shoulder is freely movable, not so the hip.

SUMMARY

- **HUMAN BODY**
  - **Dorsal Cavity**
    - *a.* **Cranial cavity** — Brain.
    - *b.* **Spinal canal** — Spinal cord.
  - **Ventral Cavities**
    - *a.* **Orbital cavity**
      - Eye.
      - Optic nerve.
      - Muscles of the eyeball.
      - Lacrimal apparatus.
    - *b.* **Nasal cavity**
      - Structures forming the nose.
    - *c.* **Buccal cavity**
      - Tongue.
      - Teeth.
      - Salivary glands.
    - *d.* **Thoracic cavity**
      - Œsophagus — Trachea.
      - Lungs — Heart.
      - Blood-vessels.
    - The Diaphragm separates the thoracic and abdominal cavities.
    - *e.* **Abdominal cavity**
      - Stomach — Spleen — Pancreas.
      - Liver — Gall-bladder.
      - Large and small intestines — Kidneys (behind the peritoneum).
    - *f.* **Pelvic cavity**
      - 1. Large (false) pelvis.
      - 2. Small (true) pelvis. Bladder — Rectum. Some of the generative organs.

CHAPTER III

CELLS, TISSUES, ORGANS, AND SYSTEMS. — EPITHELIAL TISSUE — NERVE TISSUE

From the standpoint of the chemist the body is composed of *elements*. (See page 3.) From the standpoint of the anatomist the body is composed of *cells*, and they are regarded as the structural units out of which either directly or indirectly it is built. If the substance of any part of the body, *i.e.*, skin, muscle, or blood, is examined with the unaided eye, it appears homogeneous, but if examined with the microscope it is found to be composed of an innumerable number of minute cells. It is helpful to recall that low down in the scale of life we find animals so simple that they are described as consisting of just one cell. These unicellular animals are alive because they are capable of carrying on the biological functions which are essential to life. As we ascend in the scale of life, we find animals that consist of a greater number of cells. The human animal may be properly described as a multicellular animal consisting of an enormous aggregate of cells. It is important to remember that each individual cell that enters into the structure of a multicellular animal is capable of carrying on the biological functions just as the one cell that forms the unicellular animal.

Hence, all the varied activities of the body are the result of the activities of the cells which compose it, and it is very desirable that we early acquire some definite conception of these tiny elementary bodies.

CELLS

A cell[1] is a minute portion of living substance called protoplasm which is sometimes enclosed in a cell-wall. Within the pro-

[1] The word cell is from the Latin *cella* — a cavity — and was first used by botanists to describe plant cells, like those of cork and elder pith, which have cavities in their substance. It is now known that most animal cells, and many plant cells, do not have cavities, so that the name is not especially appropriate, but it is too firmly fixed in our language to be abandoned.

toplasm lies a body of definite rounded form, called the nucleus, and this in turn often contains one or more smaller bodies or nucleoli.

Cell	Protoplasm (living)	Cytoplasm.	
		Nucleus	Chromatin.
			Achromatin.
		Centrosome.	
	Metaplasm (not living)	Food.	
		Wastes.	
		Storage Products.	

Protoplasm. — Protoplasm is a general term for living substance.

Cytoplasm. — That portion of the protoplasm which surrounds the nucleus is given the name cytoplasm. Cytoplasm is therefore a regional name for a portion of the protoplasm.

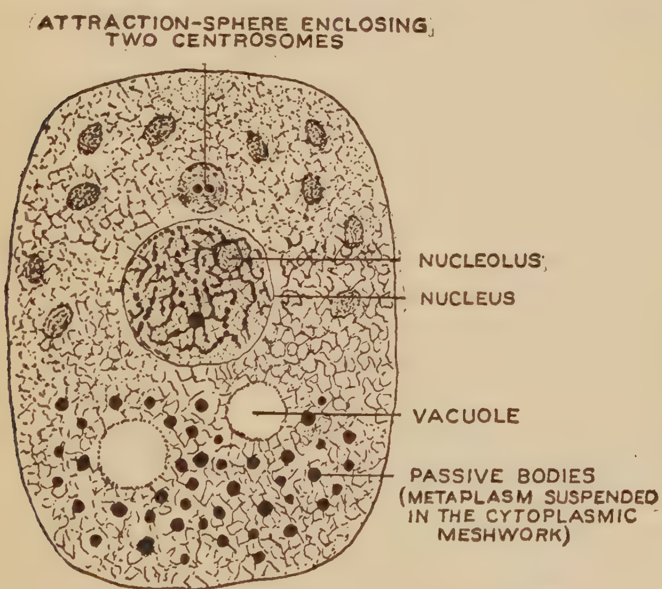


FIG. 6. — DIAGRAM OF A CELL. (Modified from Wilson.)

Nucleus. — That portion of the protoplasm inside the nuclear membrane is called the nucleus. It is more solid, differs in chemical composition, and may or may not contain the minute spherical bodies termed *nucleoli.* In red blood cells no nucleus can be found. It is known, however, that when first formed each has a nucleus though it is lost in the course of development. If an attempt

is made to dye the nucleus with chromatin dyes, certain portions will take the dye, other portions will not. The material which can be dyed is called chromatin, the matter which cannot be dyed is called achromatin.

Centrosome. — An actively multiplying cell contains a minute structure called the centrosome which is associated with the reproductive function. It is found in or near the nucleus, and is usually surrounded by a mass of slightly differentiated cytoplasm called the attraction sphere.

Metaplasm. — In the meshwork of protoplasm are often suspended various passive bodies, such as food granules, pigment bodies, drops of oil, etc. These may represent reserve food matters, or waste matters, and are collectively designated as metaplasm, or non-living substances.

Life activities in cells. — Since the body is composed of cells, it follows that all the activities of the body are the result of the activities of the cells. These activities are designated as the biological functions which are essential to life. They may be enumerated as follows: —

(1) *Support.* — Each cell is afforded support by the cohesiveness of its own structure; by the cell-wall if one exists; if not, then the outer circumference of the protoplasm approximates the function of a membranous support.

(2) *Respiration.* — Each cell coming in contact with oxygen absorbs it. Whenever this absorption takes place a certain amount of the cell-contents is burned or oxidized, and as a result of this oxidation heat and other kinds of energy are produced, and carbon dioxide, which is a waste product, is formed. Thus it will be seen that the real purpose of respiration is to furnish oxygen to each individual cell, and to take from the cell the carbon dioxide which it does not need.

(3) *Metabolism.* — Each cell is able to take to itself, and eventually convert into its own substance, certain materials (foods) that are non-living; in this way the protoplasm may increase in amount, or, in other words, the cell may grow. The amount of protoplasm is not permanently increased, because only enough protoplasm is added by the process of assimilation to replace that incidentally oxidized. Chemical changes which involve the building up of living material within the cell have received the

general name of *anabolic* changes, or *anabolism;* on the other hand, those which involve the breaking down of such material into other and simpler products are known as *katabolic* changes, or *katabolism*, while the sum of all the anabolic and katabolic changes which are proceeding within the cell is spoken of as the *metabolism* of the cell. These chemical changes are always more marked as

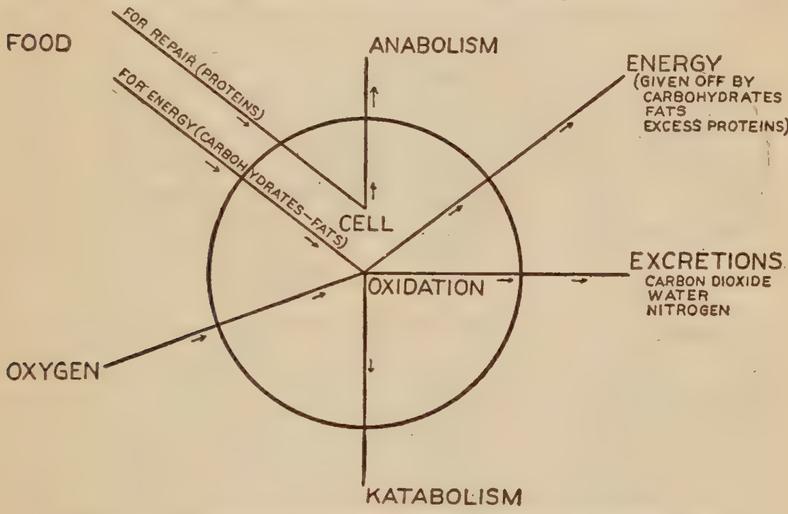


FIG. 7.—DIAGRAM SHOWING PROCESS OF METABOLISM IN A CELL.

the activity of the cell is promoted by warmth, electrical or other stimulation, the action of certain drugs, etc.

(4) *Motion.* — This is exhibited in two different forms: —

(*a*) *Amœboid movement.* — This term is derived from the amœba, a single-celled organism. It consists in the pushing outward by the cell of processes, called pseudopodia. These may be retracted or the contents of the cell may flow into them. In this way the cell may change both its shape and position. By a repetition of this process the cell may move slowly away from its original situation, so that an actual locomotion takes place.

(*b*) *Ciliary movement.* — This is the whipping motion possessed by little hair-like processes called cilia, which project from the surface of some epithelial cells.

(5) *Circulation.* — This consists in a "streaming" of the protoplasm, which occurs within the limits of the cell. By this means nutritive material or waste substances may be carried from one portion of the cell to another.

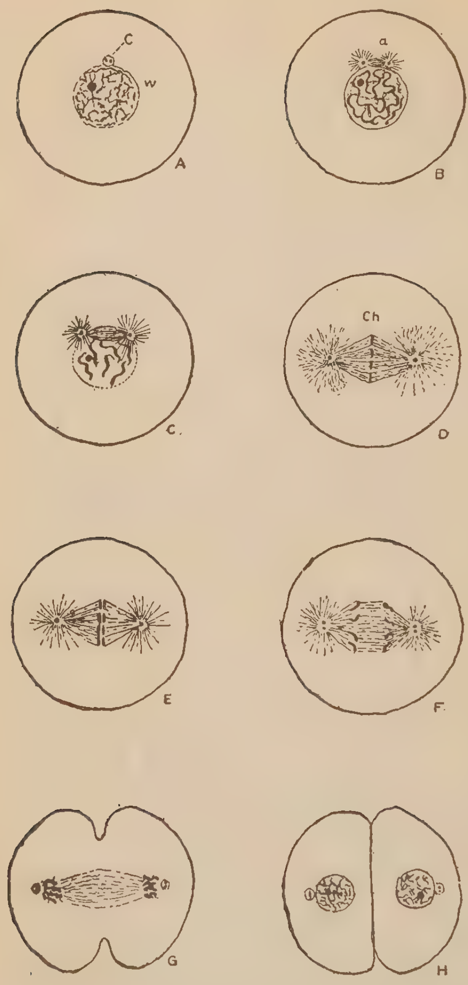


FIG. 8. — DIAGRAMS TO SHOW THE SEQUENCE OF EVENTS IN MITOSIS. *A*, resting cell with nucleus (*n*) and centrosome (*c*). *B*, preparing to divide, two asters (*a*) near nucleus, each with a centrosome, chromatin being massed into chromosomes. *C*, centrosomes separating forming a spindle between them, nuclear membrane disappearing, chromosomes formed. *D*, chromosomes (*ch*) lying in the equator of the spindle. *E*, chromosomes divided lengthwise into halves. *F*, chromosomes separating and moving toward the centrosomes. *G*, chromosomes forming the two nuclei, and cell body, beginning to divide. *H*, division complete, two-cell stage; each cell has the same structure as the one-cell in *A*. (Modified from Wilson.)

(6) *Excretion.* — Each cell is able to discharge and thus get rid of waste substances.

(7) *Irritability.* — Irritability is that property which enables a cell to respond to external stimuli. Cells vary in regard to their irritability, the most markedly irritable cells in higher animals being those of the nervous system.

(8) *Cell division.* — Like all living organisms, each cell grows, produces other cells, and dies, so that each cell has a life cycle comparable to, but much shorter than, the body itself. As the cells are constantly dying, the need for constant reproduction is apparent. This reproduction is accomplished in two ways, (*a*) simple direct division and (*b*) indirect division or mitosis which is the almost universal method.

(*a*) In direct division the cell elongates, the nucleus and cytoplasm become constricted in the centre, and the cell divides and forms two cells which soon grow to the size of the original cell.

(*b*) In indirect division, or *mitosis*, the nucleus passes through a series of remarkable changes which are rather complicated. A careful study of Fig. 8 will give the student some idea of these changes.[1]

Differences in cells. — Cells differ in (1) size, (2) form, (3) chemical composition, and (4) function. (1) As an example of variation in size [2] a voluntary muscle cell is about an inch (25 mm.) long and $\frac{1}{500}$ of an inch (0.05 mm.) in diameter. The processes of a nerve cell may be 3 feet (1 metre) or more in length. A red blood cell has a diameter of $\frac{1}{3200}$ of an inch (about 0.008 mm.). (2) The simplest form of cell is spherical, but this is seldom realized except in unicellular plants and animals. In the human body the form of the cell is modified by the pressure of the surrounding structures, by active movement of the cell substance, and by growth and differentiation. (3) It is assumed that the marked difference in the appearance of cells is an expression of a chemical difference, which in turn is an evidence of difference in function. (4) A unicellular animal is in itself a complete living thing, and thus one cell must perform all the essential activities of life, and is self-sufficient. In multicellular animals there is a physiological division of labor among the cells, *i.e.*, certain cells have become specialized in some one essential activity which they perform for the whole complex, and certain others have become specialized to perform other essential activities for the whole,

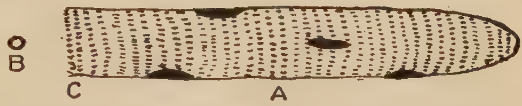


Fig. 9. — Sizes of Cells. *A*, voluntary muscle cell magnified in width 200 times and represented as cut off at *C*. At this magnification it would be about 200 inches long. *B*, red blood cell, also magnified about 200 times.

[1] For a detailed description of mitosis the student is referred to "The Cell in Development and Inheritance," by Wilson.

[2] On page 491 will be found accurate ratios between the metric system and the system of lengths, weights, and measures used in the United States. For the sake of simplicity in converting figures in the text from one system to the other, we have assumed

1 cm. to equal $\frac{2}{5}$ in. (25 mm. = 1 in.).
1 cc. to equal 15 minims.
30 gm. to equal 1 oz. (dry or liquid measure).
30 cc. to equal 1 oz. (dry or liquid measure).
1 litre to equal 1.75 pt. (dry measure).
1 litre to equal 2.11 pt. (liquid measure).

i.e., the function of muscle cells is to contract, and the combined contraction of a group of muscle cells results in the contraction of a muscle.

TISSUES

The cells of the body are arranged in groups called tissues. Each tissue is a collection of cells of like substance arranged together and having some specialized function to perform for the body. In many tissues, all the substance is not inside the cell-walls, some of it is between the cells or *intercellular*. In the muscles there is a cement substance between the cells which holds them together. In some tissues there is very little intercellular substance, in others there is a large proportion of it.

ORGANS

When two or more different tissues are associated in performing some special office in the body, the part so adapted is termed an organ. Thus, the bones are organs specially adapted for support and locomotion, the kidneys for secreting urine, etc. As the structure of an organ depends upon the properties of the tissues composing it, so the characteristics of each tissue depend upon their ultimate structural units — the cells and the intercellular substance.

SYSTEMS

An arrangement of organs closely allied to each other and set apart to perform some general function is spoken of as a system. Eight systems are found in the human body. Their names with the functions of each are briefly expressed as follows: —

Skeletal system. — Support.

Respiratory system. — To provide oxygen and get rid of carbon dioxide.

Alimentary system. — To receive, digest, and absorb the food which is to be used by the cells.

Muscular system. — Contraction which results in motion.

Vascular system. — Distribution of the body fluids to all the cells.

Excretory system. — To eliminate the waste products that result from cell activity.

Nervous system. — To control and insure coördination in the working of all the systems in the body. Contains the centres for all the sensations, intelligence, and thought that we recognize as the highest functions of life.

Reproductive system. — To insure the continuance of the race by the production of other beings.

It is important for the student to remember that these different systems are closely interrelated and dependent on each other. While each forms a complete unit, specially adapted for the performance of some function, yet that function cannot be properly performed without the assistance and coöperation of other systems. The most perfect skeleton is not capable of support unless assisted by the muscular and nervous systems. Any interference with the circulatory system also affects the work of the excretory system, etc.

CLASSIFICATION

By the aid of the microscope the different distinct tissues of which the body is formed are found to be comparatively few in number, and some of these, although at first sight apparently distinct, yet have so much in common in their structure and origin, one with another, that the number becomes still further reduced, until we can distinguish only four distinct tissues, viz.: —

1. The epithelial tissues.
2. The nerve tissues.
3. The connective tissues.
4. The muscular tissues.

Such fluids as blood and lymph are frequently described as liquid tissues.

Origin of tissues. — It has been stated that the cell is the structural unit of the body, and in the beginning the body develops from a single cell called a *zygote* which is formed by the union of the ovum and the spermatozoön. The ovum is developed in the ovary and is made fertile by the entrance into it of a cell, known as the spermatozoön formed in the testes of the male. After fertilization takes place the zygote divides and subdivides until an enormous number of cells is formed. The cells thus formed arrange themselves in the form of a membrane, *blastoderm,* which is composed of three layers. These layers are known respectively as *ectoderm, mesoderm,* and *entoderm.*

The *ectoderm*, or outer layer, forms the epidermis and the nervous system.

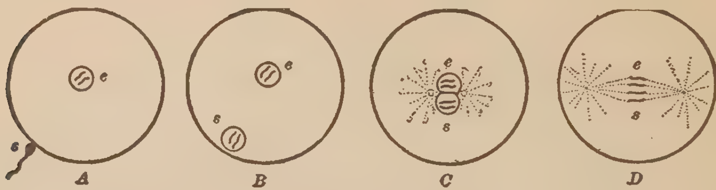


FIG. 10. — DIAGRAMS TO ILLUSTRATE FERTILIZATION OF AN EGG-CELL (OVUM) BY A SPERM-CELL (SPERMATOZOÖN). *A*, *e*, nucleus of a matured egg-cell; *s*, a sperm-cell ready to enter. *B*, sperm-cell entered and transformed into sperm-nucleus (*s*). *C*, sperm-nucleus and egg-nucleus united, fertilization complete, zygote formed. *D*, division leading to two-cell stage. (Bigelow.)

The *mesoderm*, or middle layer, forms the circulatory and most of the genito-urinary systems, also the muscles, bones, and other connective tissues.

The *entoderm* or inner layer forms the greater part of the lining of the alimentary and respiratory tracts, also the liver, pancreas, and other glands.

EPITHELIAL TISSUE

Epithelial tissue is composed entirely of cells united by cement substance. The cells are generally arranged so as to form a skin, or membrane, covering the external surfaces, and lining the internal parts of the body. This membrane is seen when the skin is blistered, the thin and nearly transparent membrane raised from the surface being epithelial tissue — in this situation called *epidermis*, because it lies upon the surface of the true skin. In other situations, epithelial tissue usually receives the general name of *epithelium*.

We may classify the varieties of epithelium according to the shape of the cells which compose them, or according to the arrangement of these cells in layers. Adopting the latter and simpler classification, we distinguish three main varieties: —

1. **The simple, consisting of a single layer of cells.**
2. **The transitional, consisting of two or three layers.**
3. **The stratified, consisting of many layers.**

1. **Simple epithelium.** — This is composed of a single layer of cells. The cells forming single layers are of distinctive shape,

and have distinctive functions in different parts of the body. The chief varieties are: —

a. pavement *b. columnar* *c. ciliated*

(*a*) *Pavement epithelium.* — This is also called squamous or scaly epithelium. The cells form flat, many-sided plates or scales, which fit together like the tiles of a mosaic pavement. It forms very smooth surfaces, and lines the heart, blood-vessels, lymphatics, and the serous cavities, etc.

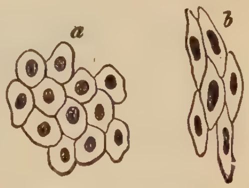


FIG. 11.—SIMPLE PAVEMENT EPITHELIUM. *a*, from a serous membrane; *b*, from a blood-vessel.

(*b*) *Columnar epithelium.* — The columnar epithelium is a variety of simple epithelium in which the cells have a prismatic shape, and are set upright on the surface which they cover. In profile these cells look somewhat like a close palisade. They taper somewhat toward their attached end, which is set upon a basement membrane. Columnar epithelium is found in its most characteristic form lining the intestinal canal.

FIG. 12.—SIMPLE COLUMNAR EPITHELIUM. *a*, the cells; *b*, intercellular substance between the lower end of cells.

(*c*) *Ciliated epithelium.* — In ciliated epithelium the cells, which are generally columnar in shape, bear at their free surface little hair-like processes, which are agitated incessantly with a lashing or vibrating motion. These minute and delicate processes are named *cilia*, and are active prolongations of the cell-protoplasm. The manner in which cilia move is best seen when they are not acting very quickly. The motion of an individual cilium may be compared to the lash-like motion of a short-handled whip, the cilium being rapidly bent in one direction. The motion does not involve the whole of the ciliated surface at the same moment, but is performed by the cilia in regular succession, giv-

FIG. 13. — CILIATED EPITHELIUM FROM THE HUMAN TRACHEA. (Highly magnified.) *a*, large ciliated cell; *d*, cell with two nuclei.

ing rise to the appearance of a series of waves travelling along the surface like the waves tossed by the wind in a field of wheat. When they are in very rapid action, their motion conveys the idea of swiftly running water. As they all move in one direction, a current of much power is produced.

In man their use is to impel secreted fluids, or other matters, along the surfaces from which they extend; as, for example, the mucus of the trachea and nasal chambers, which they carry toward the outlet of these passages.

2. **Transitional epithelium.** — This consists of two or three layers of cells. The superficial cells are large and flattened, hav-

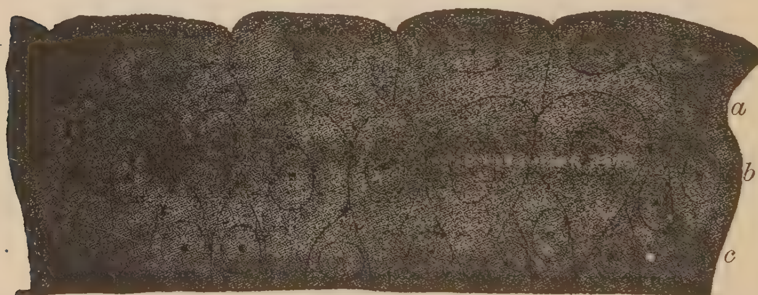


Fig. 14. — Section of the Transitional Epithelium Lining the Bladder. (Highly magnified.) *a*, superficial; *b*, intermediate; *c*, deep layer of cells. (Schäfer.)

ing on their under surface depressions into which fit the larger ends of the pear-shaped cells which form the next layer. Between the tapering ends of these pear-shaped cells are one or two layers of smaller, many-sided cells, the epithelium being renewed by division of these deeper cells. This kind of epithelium lines the bladder and ureters.

3. **Stratified epithelium.** — This consists of many layers of cells. The cells composing the different layers differ in shape. As a rule, the cells of the deepest layer are columnar in shape; the next, rounded or many-sided, whilst those nearest the surface are always flattened and scale-like. The deeper soft cells of a stratified epithelium are separated from one another by a system of channels, which are bridged across by numerous fibres. These cells are often described as prickle cells, as when separated they appear beset with spines. They are continually multiplying by

cell-division, and as the new cells which are thus produced in the deeper parts increase in size, they compress and push outward those previously formed. In this way cells which were at first deeply seated are gradually shifted outward and upward, growing harder as they approach the surface. The older superficial cells

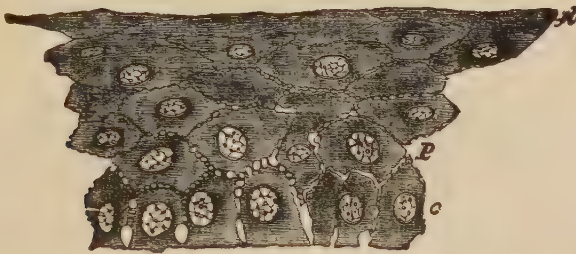


FIG. 15. — SECTION OF STRATIFIED EPITHELIUM. *c*, lowermost columnar cells; *P*, polygonal cells above these; *fl*, flattened cells near the surface. Between the cells are seen intercellular channels, bridged over by processes which pass from cell to cell. (Schäfer.)

are being continually rubbed off as the new ones continually rise up to supply their places.

Stratified epithelium covers the anterior surface of the eye, lines the mouth, the chief part of the pharynx, the œsophagus, the anal canal, part of the urethra, and in the female the vagina and neck of the uterus.

Its most extensive distribution is over the surface of the skin, where it forms the epidermis. Whenever a surface is exposed to friction, we find stratified scaly epithelium, and we may therefore classify it as a protective epithelium.

Function. — The most important functions of epithelial tissue are as follows: —

1. *Protection.* — Some varieties are specially modified so as to form protective membranes. Example — skin. Other varieties form the top layer of the mucous membranes, and mucous membranes are found lining passages that communicate with the exterior of the body. Serous membranes are also lined by epithelial cells. These serous membranes line passages that do not communicate with the exterior of the body.

2. *Motion.* — This is seen in the cilia, which tend to keep the passages from which they extend clean and free from foreign material.

3. *Absorption.* — This is particularly well seen in the digestive tract.

4. *Secretion.* — Every secreting organ must contain epithelial cells. Mucous and serous membranes are examples of secreting organs.

5. *Special sensation.* — The organs of the special senses contain epithelial cells. Examples — eye, ear, nose, etc.

NERVE TISSUE

Nerve tissue like all other tissues is composed of cells which are differentiated from other cells in that their protoplasm is extended, often to a distance of two or three feet, to form thread-like processes or conductors. The cells and their processes are held in place by a peculiar form of connective tissue called neuroglia or glia tissue. (See page 50.) The cells of the nervous system are called neurones.

NEURONES

Although the neurones vary considerably in size and form, they possess certain structural characteristics in common. They consist of: —

(1) The cell-body

(2) The cell-processes

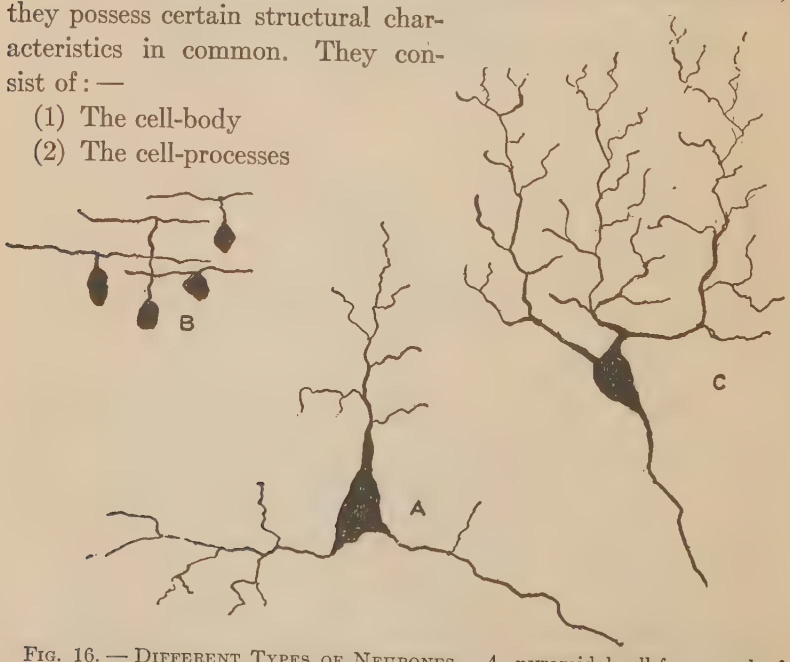


FIG. 16. — DIFFERENT TYPES OF NEURONES. *A*, pyramidal cell from cerebral cortex. *B*, bipolar cells of the Spinal Sensory Ganglia. *C*, cell of Purkinje from the Cerebellum. (Burton-Opitz.)

These two parts make up a complete nervous entity, and the entire nervous system consists of an enormous number of neurones.

(1) **The cell-body.** — The cell-bodies vary as to size and shape, but all varieties present certain common characteristics. A typical cell-body consists of a mass of granular cytoplasm surrounding a large, well-defined nucleus. The latter in turn contains a nucleolus. From the angles of the cell-body are given off processes. Each cell-body has at least one process and may have many more.

Function of the cell-body. — The cell-body affords nutriment to its processes, as is proven by the fact that if a nerve-fibre is cut, the part separated from the cell-body dies. Moreover, they are capable of modifying impulses brought to them by their sensory processes. This modification may take the form of *inhibition* and either partially or completely block impulses; or it may take the form of *summation, i.e.,* collect weak impulses, and combine them into one effective impulse before transmission to the motor nerves.

(2) **The cell-processes.** — The cell-processes are named as follows: —

(*a*) Dendrites or dendrones.

(*b*) Axones, or axis cylinder processes, named also neuraxones.

(*a*) *Dendrites.* — These processes are usually short, and rather thick at their attachment to the cell-body. They have a rough outline, diminish in calibre as they extend further from the cell-body, and branch in a tree-like manner. The number of dendrites varies.[1]

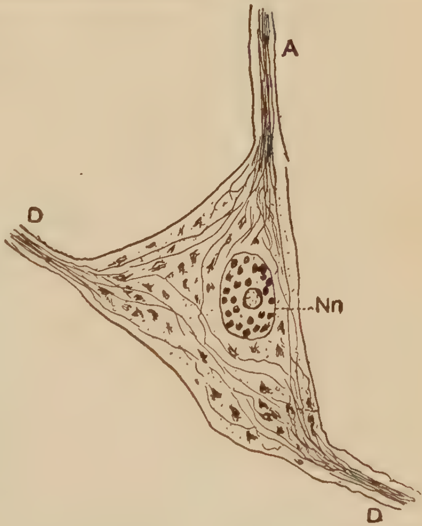


FIG. 17. — CELL-BODY. *A*, axone. *D*, *D*, dendrites. *Nn*, nucleus and nucleolus. (Burton-Opitz.)

(*b*) *Axones.* — The axone differs from the dendrite in the following particulars: —

[1] The neurones in the spinal ganglia are exceptional, having long dendrites and comparatively short axones.

(1) It is usually longer; in some instances its length may equal half a man's stature.

(2) It has a smooth outline and diminishes in calibre very little.

(3) It gives off one or more minute side branches called *collaterals*.

Function of the processes. — The essential function of the processes is conduction of nerve impulses either to the cell-body, or from the cell-body. Those which carry impulses *to* the cell-body are called *afferent;* those which carry impulses *from* the cell-body are called *efferent*.

Nerve-fibre. — The term *nerve-fibre* is only another name for the axone. These processes as they extend away from the cell become surrounded with sheaths; it is therefore advisable to describe the nerve-fibre separately as though it were a new subject.

Nerve-fibres are of two kinds: medullated, or white fibres, and non-medullated, or gray fibres.

Medullated fibre. — If one looks at a medullated nerve-fibre under the microscope, it is found to consist of three parts: —

(1) A central core which is a continuation of the axone; (2) immediately surrounding the axone is a sheath, or covering, of a semi-fluid, fatty substance called the *myelin sheath*. It is to this fatty substance that medullated nerve-fibres owe their white color. (3) External to the myelin sheath is a thin membrane completely enveloping the nerve-fibre and forming the outer covering called the *neurilemma*.

Function of the myelin sheath. — It is supposed that the myelin sheath serves: (1) as a source of nourishment, (2) as a protection, and (3) as a non-conducting medium for the fibre. In the last-mentioned capacity it is thought that this sheath prevents the deflection of nerve-impulses from their intended course, in some such way as the insulation of an electric wire prevents the current from taking a path other than the one desired.

Nodes of Ranvier. — At regular intervals along the course of a medullated nerve-fibre, the myelin sheath is interrupted and the neurilemma brought close to the axone. These constrictions are the *nodes of Ranvier*. Thus at each node the nerve-fibre is smaller in diameter, this change being entirely at the expense of the myelin sheath, the axone remaining unchanged. These nodes are about 1 mm. apart and the portion between two consecutive

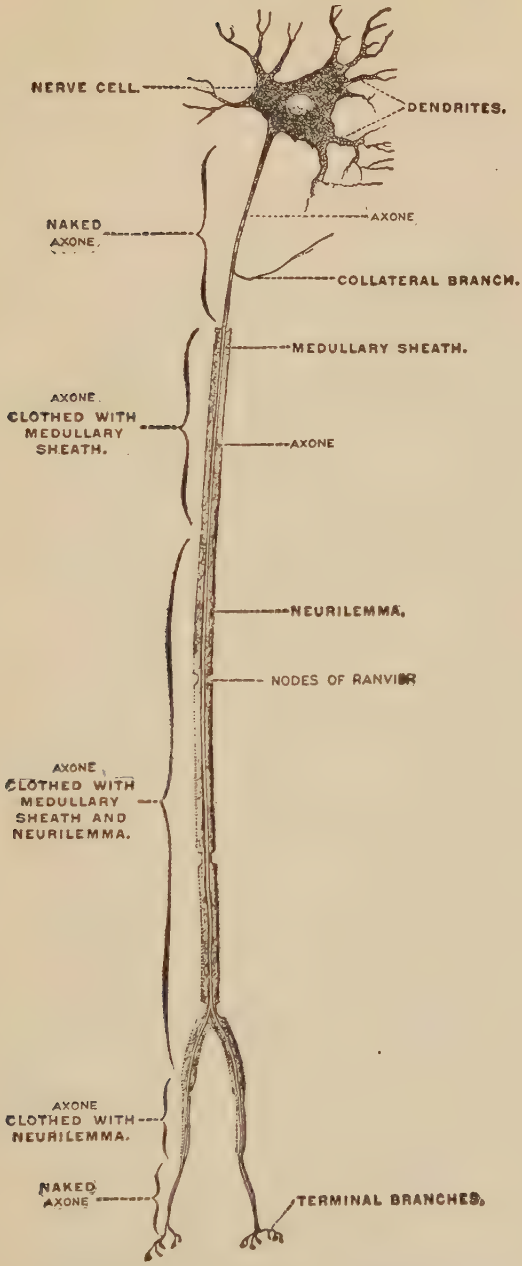


Fig. 18. — A Neurone. (Gerrish.)

nerves is called an internode. In each internode the neurilemma is seen to have a nucleus. Medullated nerve-fibres may be very long, but the diameter is very minute.

Function of the nodes of Ranvier. — The passage of blood-plasma into the fibre is rendered easier by the absence of the myelin sheath at the nodes of Ranvier, and this is thought to be their function.

Non-medullated fibre. — Non-medullated nerve-fibres or, as they are sometimes called, *the fibres of Remak*, do not differ in any respect from the medullated nerve-fibres save in the absence of the myelin sheath, the axone being directly invested by the neurilemma. Owing to the absence of the myelin sheath, the non-medullated fibres do not appear white, but present a grayish or yellow color.

Collaterals. — The minute side branches of the axones are called collaterals.

Nerve-endings. — Nerve-endings are often of different types in accordance with their function and may be classified according to the part of the body in which they are found.

1. Nerve-fibres which terminate in the brain or spinal cord split up into *end arborizations*.

End arborizations. — If the nerve-fibre is to terminate while still lying in the mass of the nervous system, its axone may split up at the termination into a number of short filaments called end arborizations, which interlock with the dendrites of another neurone, or the axone may send out collaterals which interlock with dendrites.

2. Sensory nerve-fibres ending at the periphery of the body terminate in two ways: —

(*a*) *Inter-epithelial arborizations.* — This is the most common mode of termination of sensory nerves. The nerve-fibres pass to the surface either in the skin or mucous membrane; the neurilemma and myelin sheath disappear, the naked axone subdividing into minute *arborizations* that ramify between the epithelial cells of the surface of the body. This method is the one in which nerves terminate in various glands, hairs, teeth, tendons, etc.

(*b*) *Organules.* — Some of the highly complex special sensations need very complex end organs for their reception. These end organs are modified epithelial cells and are called organules. The

axone subdivides into arborizations as described above; and these enter and terminate in the organules. The different varieties of *tactile corpuscles*, the *organ of Corti*, for the auditory nerve, and the *rods* and *cones* of the retina may be cited as examples of organules.

3. Motor nerve-fibres ending in voluntary muscles terminate in *motor plates*.

Motor plates. — A nerve intended to stimulate a muscle to activity terminates by a subdivision of the axone (the neurilemma

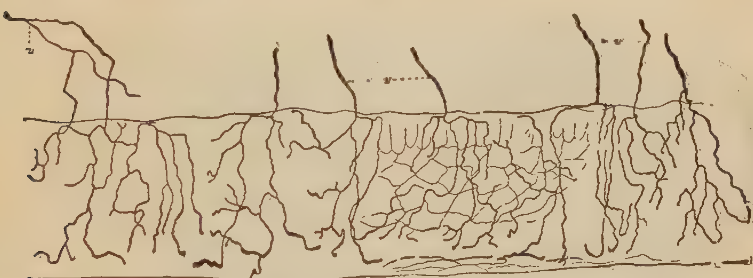


FIG. 19. — SENSORY NERVE TERMINATIONS IN STRATIFIED PAVEMENT EPITHELIUM. (Kirkes.)

and myelin sheath fading out), each branch of the axone ending in a flat nodule of granular material lying on the muscle fibre. This terminal mass is the motor plate.

4. Motor nerve-fibres ending in involuntary muscles (such as in the viscera) terminate in a *plexus*.

Plexus. — The nerve-fibres which are distributed to the viscera are non-medullated, and near their terminations each one divides into a number of branches which arborize with each other and form a network or plexus. From this plexus smaller branches are given off, these subdivide to form fibrils, and the fibrils terminate on the surface of the muscle cells.

Formation of nerves. — The nerve-fibre of each neurone is, as has been described, of microscopic diameter, but when a number of these nerve-fibres are bound together in a bundle we have the plainly visible nerves, such as are seen in dissections of the body. Between the individual nerve-fibres is a small amount of connective tissue which serves not only to bind the fibres together into bundles, or *funiculi*, but also to carry to or from the fibres the blood-vessels and the lymphatics necessary for their nutrition. Connective tissue also surrounds these bundles in the form of a sheath.

Although the nerves branch frequently throughout their course, and these branches often meet and fuse with one another, or with the branches of other nerves, yet each axone always remains quite distinct. The nerve is thus merely an association of individual fibres which have very different activities and which may function

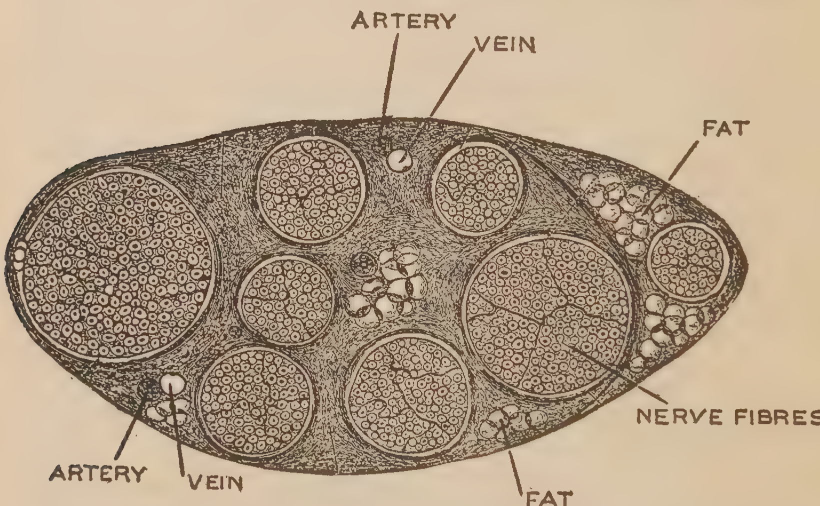


Fig. 20. — Transverse Section of the Sciatic Nerve of a Cat about × 100. This nerve consists of eight bundles (funiculi) of nerve-fibres. Each bundle has its own wrappings and all the bundles are embedded in connective tissue in which arteries, veins, and fat cells can be seen.

entirely independent of one another. Perhaps the best idea of the arrangement of nerves in a trunk can be obtained from a cross section of a nerve such as is seen in Fig. 20.

Gray and white matter. — The cell-bodies of neurones and many of their processes are grouped together into what we call gray matter. Gray matter is found in the cortex of the brain, the core of the spinal cord, and making up the ganglia. Experiments have shown that various activities of the body are controlled from certain areas in the gray matter. For instance, the rate of respiration is controlled by an area in the medulla oblongata or spinal bulb, and odor is interpreted from a certain region in the cerebrum. Regions of gray matter which function in this way we call centres, and we speak of the respiratory centre, the olfactory centre, etc. The medullated processes of cell-bodies are grouped together, as described, into nerves, and these nerves constitute what we call white matter.

THE NERVOUS SYSTEM

Nerve tissue enters into the structure of all parts of the nervous system. In other words, the nervous system exclusive of the supporting and connecting tissues is simply an aggregation of millions of neurones or nerve-cells. Regionally considered, the nervous system presents itself as (1) the central nervous system and (2) the peripheral nervous system.

Nervous System
- 1. Central Nervous System
  - Brain
    - Cerebrum.
    - Cerebellum.
    - Pons Varolii.
    - Medulla Oblongata.
  - Spinal cord.
- 2. Peripheral Nervous System
  - Cranial nerves.
  - Spinal nerves.
  - Sympathetic nervous system.

Central nervous system.— The central nervous system consists of the brain and spinal cord. The general arrangement of this system is shown in Fig. 21. The nerves connected with the brain are the cranial, those connected with the spinal cord are the spinal nerves, and both of these systems of nerves together are called the cerebrospinal nerves, in contrast to the sympathetic nerves.

Ganglion. — The term *ganglion* is used to describe a collection of neurones outside the central nervous system. Ganglia appear in the course of the cranial and spinal nerves and form the chief mass of the sympathetic system.

Fig. 21. — Diagram Illustrating the Brain, Spinal Cord, and Spinal Nerves.

Sympathetic system. — The sympathetic or autonomic nervous system consists of innumerable ganglia and nerves distributed very widely throughout the body, chiefly to the viscera. It is closely connected with the central nervous system through bridges of nerves, known as the white and gray communicating rami.

Properties of nerve tissue. — Nerve tissue is the most highly specialized tissue in the body. It possesses the following marked characteristics: (1) irritability or the power to respond to stimulation, and (2) conductivity or the power to transmit the stimulus or nerve impulse to the muscles, viscera, etc.

For a fuller discussion of the **Nervous System** see Chapter XIX.

SUMMARY

The human body is an enormous aggregate of cells. A cell is a minute portion of protoplasm, sometimes enclosed in a cell-wall. May contain a nucleus which in turn often contains nucleoli.

- **Cell**
  - Protoplasm (living)
    - Cytoplasm — protoplasm surrounding nucleus.
    - Nucleus — protoplasm inside the nuclear membrane. Contains chromatin and achromatin.
    - Centrosome — found in actively multiplying cells.
  - Metaplasm (not living)
    - Food.
    - Wastes.
    - Storage products.
- **Life activities in cells**
  - 1. Support.
  - 2. Respiration
    - Combines with oxygen = oxidation.
    - Liberates heat.
    - Carbon dioxide formed.
  - 3. Metabolism
    - Anabolism = building-up process.
    - Katabolism = breaking-down process.
  - 4. Motion
    - (*a*) Amœboid movement.
    - (*b*) Ciliary movement.
  - 5. Circulation — Streaming of the protoplasm, within the limits of the cell.
  - 6. Excretion — Discharge of waste substances.
  - 7. Irritability — Ability to respond to stimuli.
  - 8. Cell division
    - (*a*) Simple, direct division.
    - (*b*) Indirect division or mitosis.

Differences in cells
- Size
  - Voluntary muscle cell an inch long.
  - Processes of nerve cells may be three feet or more.
  - Red blood cell $\frac{1}{3200}$ inch in diameter.
- Form depends on
  - Pressure.
  - Movements of cell.
  - Growth and differentiation.
- Chemical composition — dependent on special work of cell.
- Function — assist in work of tissue of which it forms a part.

Tissues — are made up of a collection of cells of like substance, with more or less intercellular substance between the cells.

Organs — are made up of two or more tissues associated to perform a common function.

System. — A group of organs set apart to perform some special function. Eight systems are found in the human body.

Skeletal.	Vascular.
Respiratory.	Excretory.
Alimentary.	Nervous.
Muscular.	Reproductive.

Classification of tissues
1. Epithelial.
2. Nerve.
3. Connective.
4. Muscular.

Origin of tissues
- (*a*) Impregnation.
- (*b*) Multiplication of cells.
- (*c*) Formation of Blastoderm
  - Ectoderm
    - Epidermis.
    - Nervous system.
  - Mesoderm
    - Circulatory system.
    - Most of the genito-urinary system.
    - Muscles.
    - Connective tissues.
  - Entoderm
    - Lining of respiratory tract.
    - Lining of alimentary tract.
    - Liver, pancreas, and other glands.

Epithelial — a tissue of cells and little intercellular substance.

Classification of epithelial tissue
- **Simple**, consisting of a single layer
  - Pavement or scaly.
  - Columnar.
  - Ciliated.
- **Transitional**, consisting of 2 or 3 layers.
- **Stratified**, consisting of many layers.

Function
- Protection.
- Motion.
- Absorption.
- Secretion.
- Special sensation.

Nerve tissue. — A tissue of differentiated cells called neurones held in place by neuroglia.

- **Neurone**
  - Cell-body
    - Cytoplasm surrounds nucleus.
    - Nucleus may or may not contain nucleolus.
    - Function
      - Nutritive centre.
      - Modifies impulses
        - Inhibition.
        - Summation.
  - Cell-processes
    - Dendrites
      - Usually short, break up into many branches. Rough outline — diminish in calibre. May be one, or many.
    - Axone
      - Long, smooth outline, diminishes very little. Gives off collaterals.
    - Function is conduction of nerve impulses either *to* the cell-body (afferent), or *from* the cell-body (efferent).

- **Nerve-fibre**
  - Medullated
    - Axone
    - Myelin sheath — function
      1. Source of nourishment
      2. Non-conducting medium.
    - Neurilemma
  - Non-medullated
    - Axone.
    - Neurilemma.

- **Nodes of Ranvier**
  - Ring-like constrictions in medullated fibres, due to absence of myelin sheath.
  - Function — Passage of blood-plasma to fibre rendered easier.

Collaterals. — Minute side branches given off from axones.

- **Nerve-endings**
  1. End arborizations — terminations in brain or cord.
  2. Inter-epithelial arborizations; Organules — Terminations of sensory fibres at the periphery of the body.
  3. Motor plates — terminations of motor nerve-fibres in voluntary muscle.
  4. Plexus — terminations of motor nerve-fibres in involuntary muscle.

- **Nerves**
  - Bundles of nerve-fibres bound together to make funiculi.
  - Funiculi bound together to make nerve-trunks.
  - Connective tissue surrounds funiculi and nerve-trunks.

- **Classification of nerve tissue**
  - Gray matter
    - Cell-bodies of neurones and many of their processes.
    - Found in
      - Cortex of brain.
      - Core of spinal cord.
      - Ganglia.
    - Centres — Groups of neurones exercising control over some definite function.
  - White matter
    - Myelinated processes of cell-bodies are grouped together into nerves, and these constitute white matter.

Nervous system	1. Central nervous system	Brain	Cerebrum. Cerebellum. Pons Varolii. Medulla oblongata.
		Spinal cord.	
	2. Peripheral nervous system	Cranial nerves Spinal nerves Sympathetic nervous system.	

Properties of nerve tissue	1. Irritability or the power to respond to stimulation. 2. Conductivity or the power to transmit stimuli.

CHAPTER IV

CONNECTIVE TISSUES: AREOLAR, FIBROUS, ELASTIC, ADIPOSE, RETICULAR, NEUROGLIA, CARTILAGE, BONE

Following the classification of tissues we have adopted, the next group to be studied is that known as the connective tissue group.

Our description of epithelial tissue was briefly this: a skin or membrane formed of cells, which cells may be of a variety of shapes, and be arranged in one or more layers. It is distinctly a tissue of cells with very little of what we call intermediate or intercellular substance lying between the cells. Connective tissue differs from epithelial tissue in having a great deal of intercellular substance lying between the cells. It may be interesting to note that in this form of tissue, the intercellular substance is supposed to develop from the cells.

CONNECTIVE TISSUE GROUP

These tissues differ considerably in their external characteristics, but are alike (1) in that they all serve to connect and support the other tissues of the body; (2) they[1] are all developed from the mesoderm; (3) the cellular element is at a minimum, and the intercellular material is at a maximum; (4) they originate no action but are acted upon by the other tissues. We may therefore group them together as follows: —

1. **Areolar** tissue.
2. **Fibrous** tissue.
3. **Elastic** tissue.
4. **Adipose** tissue.
5. **Reticular** tissue.
6. **Neuroglia.**
7. **Cartilage.**
8. **Bone** or **osseous** tissue.

Areolar tissue. — This tissue appears to be composed of a multitude of fine threads or films, called fibres. Viewed with a microscope, these fibres are seen to be principally made up of wavy

[1] With one exception, neuroglia. See page 50.

bundles of exquisitely fine, transparent, white fibrils, and these bundles intersect in all directions. Mixed with the white fibres are a certain number of yellow elastic fibres, which do not form bundles, and have a straight instead of a wavy outline. Between these fibres are open spaces, called areolæ.[1] These spaces contain a semifluid ground substance or matrix and communicate freely

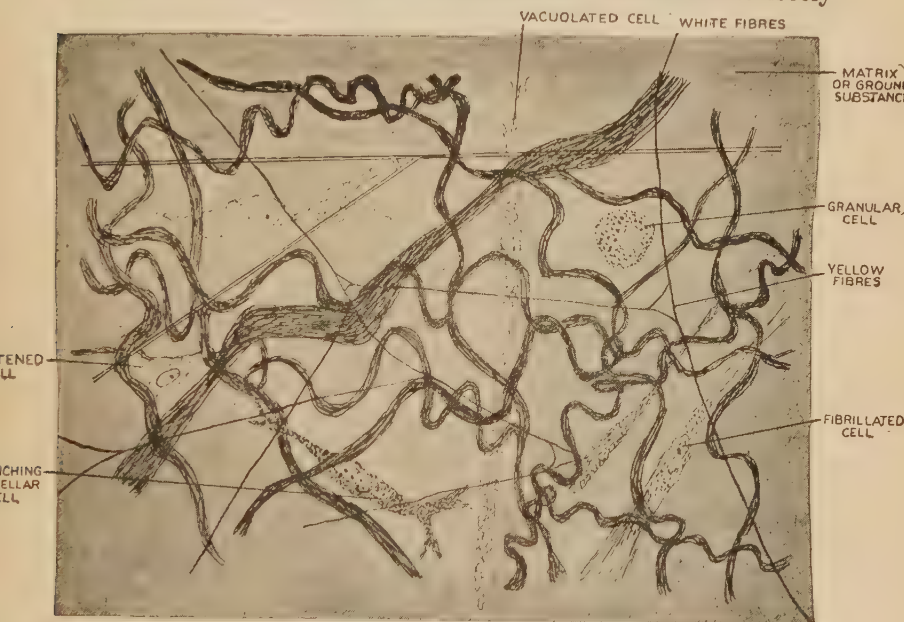


FIG. 22. — SUBCUTANEOUS AREOLAR TISSUE FROM A YOUNG RABBIT. (Highly magnified.) The white fibres are in wavy bundles, the elastic fibres form an open network. (Schäfer.)

with one another. Lying in the areolæ between the bundles of fibres are seen the tissue-cells, of which there are many varieties.

If we make a cut through the skin of some part of the body where there is no subcutaneous fat, as in the upper eyelid, and proceed to raise it from the parts lying beneath, we observe that it is loosely connected to them by a soft, filmy substance of considerable tenacity and elasticity. This is areolar tissue.

Function. — Areolar tissue forms web-like binding and supporting material and serves to connect and insulate entire organs. It is one of the most general and most extensively distributed of the tissues. It is, moreover, continuous throughout the body,

[1] Areola is the Latin word for "a small space." Areolar tissue gets its name from appearing full of minute spaces.

and from one region it may be traced without interruption into any other, however distant, — a fact not without interest in practical medicine, seeing that in this way air, water, pus, and other fluids, effused into the areolar tissue, may spread far from the spot where they were first introduced or deposited.

Fibrous tissue. — This tissue is intimately allied in structure to the areolar tissue. It consists almost wholly of wavy white fibres, which cohere very closely and are arranged side by side in bundles which have an undulating outline. The spaces between the bundles are occupied by cells arranged in rows, but the cells are not a prominent feature of this tissue. The fibres may be some inches long, do not branch, and confer a distinctly fibrous aspect on the parts which they compose.

FIG. 23. — FIBROUS TISSUE, FROM THE LONGITUDINAL SECTION OF A TENDON. The spaces between the bundles of fibres are occupied by rows of cells. (Gegenbauer.)

Fibrous tissue is white, with a peculiarly shining, silvery aspect. It is exceedingly strong and tough, yet perfectly pliant; but it is almost devoid of extensibility and is very sparingly supplied with nerves and blood-vessels.

Function. — Fibrous tissue is met with in the form of: —

(1) *Ligaments.* — Ligaments are strong flexible bands, or capsules, of fibrous tissue that help to hold the bones together at the joints.

(2) *Tendons* or *sinews.* — Tendons are white glistening cords or bands which serve to attach the muscles to the bones. They are usually composed of white fibres, but may contain some yellow fibres.

(3) *Aponeuroses.* — Aponeuroses are flat, wide bands of fibrous tissue which serve to connect one muscle with another.

(4) *Protecting sheaths* or *membranes.* — Fibrous tissue is found investing and protecting different organs of the body. Examples — heart and kidneys.

(5) *Fasciæ.* — The word *fascia* means a band or bandage. It is most frequently applied to sheets of fibrous membrane which are

wrapped around muscles, and serve to hold them in place. Fasciæ are divided into two groups, which are associated with the skin and the muscles. They are called: —

a. Superficial.

b. Deep.

a. Superficial fasciæ. — The subcutaneous areolar tissue, which forms a nearly continuous covering beneath the skin, is classed as superficial fascia. It varies in thickness, and usually permits free movement of the skin on the subjacent parts.

The fascia covering the palms of the hands is named palmar fascia, and the fascia covering the soles of the feet is named plantar fascia. The palmar and plantar fasciæ are much thicker, stronger, and more closely attached than the superficial fasciæ in other parts of the body.

b. Deep fasciæ. — The deep fasciæ are sheets of white, flexible fibrous tissue, employed to envelop and bind down the muscles, also to separate them into groups. (See page 98.) The term *fasciæ*, unless limited by an adjective, is usually employed to designate the *deep fasciæ*. Subcutaneous areolar tissue is rarely called by the name fascia, though it is correctly classed as such.

Elastic tissue. — In elastic tissue the wavy white bundles are comparatively few and indistinct, and there is a proportionate development of the elastic fibres. When present in large numbers, they give a yellowish color to the tissue. This form of connective tissue is extensile and elastic in the highest degree, and wherever located, does such work as India rubber would do. It is not so strong as the fibrous variety, and breaks across the direction of its fibres when forcibly stretched.

Function. — Elastic tissue, being extensile and elastic, has a most important use in assisting muscular tissue, and so lessening the wear and tear of muscle. It is found: —

(1) Between the transverse processes of the vertebræ in elastic bands. (*Ligamenta flava.*) (See page 76.)

(2) In the walls of the blood-vessels (especially arteries), bronchial tubes, and vocal cords.

(3) Entering into the formation of the lungs and uniting the cartilages of the larynx.

These three varieties of connective tissue (areolar, fibrous, elastic) agree closely with one another in elementary structure.

It is the different arrangement of the cells and fibres, and the relative proportion of one kind of fibre to the other, that gives them their different characteristics. They are used for purely mechanical purposes.

Adipose tissue. — When fat begins to be formed, it is deposited in tiny droplets[1] in some of the cells of the areolar tissue; these droplets increase in size, and eventually run together so as to form one large drop in each cell. By further deposition of fat the cell becomes swollen out to a size far beyond that which it possessed

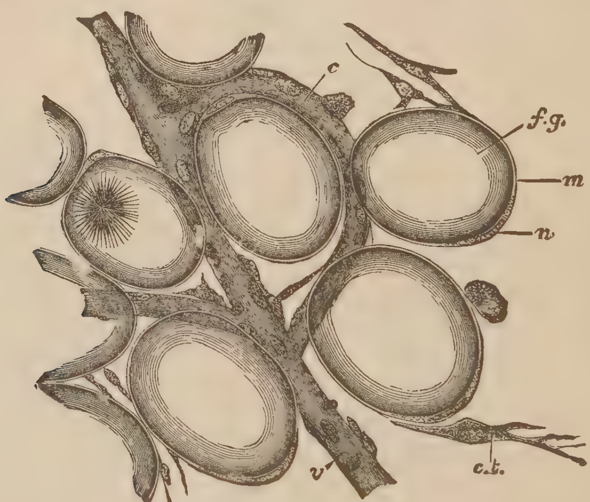


FIG. 24. — A FEW FAT CELLS FROM THE MARGIN OF A FAT LOBULE. (Very highly magnified.) *f. g.*, fat globule distending a fat cell; *n*, nucleus; *m*, protoplasmic envelope of the fat cell; *c*, capillary vessel; *v*, venule; *c.t.*, connective-tissue cell; the fibres of the connective tissue are not shown. (Schäfer.)

originally, until the protoplasm remains as a delicate envelope surrounding the fat drop. The nucleus is crowded off to one side and attached to the cell membrane. As these cells increase in number they collect into small groups or lobules, which lobules are for the most part lodged in the meshes of the areolar tissue, and are also supported by a fine network of blood-vessels. This fatty tissue exists very generally throughout the body, accompanying the still more widely distributed areolar tissue in most parts, though not in all, in which the latter is found. Still, its distribu-

[1] The contents of the fat cells of adipose tissue are fluid during life, as the normal temperature of the body is considerably above the melting point of the mixture of fats found there.

tion is not uniform, and there are some situations in which it is collected more abundantly. This tissue is found chiefly: —

(1) Underneath the skin, in the subcutaneous layer.

(2) Beneath the serous membranes or in their folds.

(3) Collected in large quantities around certain internal organs, especially the kidneys, helping to hold them in place.

(4) Filling up furrows on the surface of the heart.

(5) As padding around the joints.

(6) In large quantities in the marrow of the long bones.

Function. — Adipose tissue serves several important purposes. (1) It constitutes an important reserve fund, which can be returned to the cells by the blood and oxidized, thus producing energy. (2) It serves as a jacket or covering under the skin, and being a non-conductor of heat, prevents the too rapid loss of heat through the skin. (3) It is an admirable packing material, and serves to fill up spaces in the tissues, and thus affords support for delicate structures such as blood-vessels and nerves.

Reticular or retiform[1] tissue. — This variety of connective tissue consists of a close network of white fibres with few, if any,

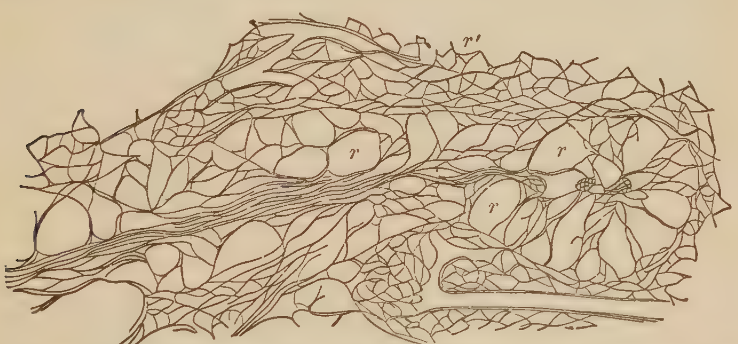


FIG. 25. — RETIFORM TISSUE FROM A LYMPH NODE. *r, r, r,* represent open meshes of this tissue. (Quain.)

yellow fibres. The meshes of the network are small and close in some parts, more open and like areolar tissue in other parts. The fibres are nearly covered by fibrous tissue cells in the form of broad, thin plates wrapped around them.

Function. — Reticular tissue forms a fine framework in many organs, *e.g.* the muscles.

[1] Reticulum (from the Latin *reticulum*, "a small net"). Resembling a small net.

Lymphoid or adenoid[1] *tissue.* — This is reticular tissue in which the meshes of the network are occupied by lymph corpuscles. This is the most common condition of retiform tissue.

Lymphoid tissue forms the principal part of the substance of the spleen and lymph nodes. It also enters into the composition of the tonsils and some of the intestinal glands.

Neuroglia. — This is a peculiar form of connective tissue found only in the nervous system. Unlike the other connective tissues it is derived from the ectoderm, not the mesoderm. It consists of cells called glia cells that give off numerous fine processes which extend in every direction and intertwine among the nerve cells and processes, forming a supporting network.

Cartilage. — This is the well-known substance called *gristle.* Although cartilage can be readily cut with a sharp knife, it is nevertheless of very *firm* consistence, but at the same time highly *elastic,* so that it readily yields to extension or pressure, and immediately recovers its original shape when the constraining force is withdrawn. When a very thin section is examined with a microscope, it is seen to consist of nucleated cells disposed in small groups in a mass of intercellular substance. This intercellular substance is sometimes transparent, and to all appearances structureless; sometimes it is pervaded with white fibres and sometimes with yellow fibres. According to the amount and texture of the intercellular substance, we distinguish three principal varieties: —

(1) *Hyaline or true cartilage.*

(2) *White fibro-cartilage.*

(3) *Yellow or elastic fibro-cartilage.*

Hyaline cartilage. — This variety is named from the Greek word for glass. A comparatively small number of cells are embedded in an abundant quantity of intercellular substance which has the appearance of ground glass.

1. Hyaline cartilage covers the ends of the bones in the joints, where it is known as articular cartilage.

2. Hyaline cartilage forms the rib cartilages, where it is known as costal cartilage.

In both these situations the cartilages are in immediate connec-

[1] Adenoid (from the Greek *aden,* "a gland," and *eidos* or "resemblance"). Pertaining to or resembling a gland.

tion with bone, and may be said to form part of the skeleton, hence are frequently described as skeletal cartilages.

Function. — The articular cartilages, in covering the ends or surfaces of bones in the joints, provide these harder parts with a thick, springy coating, which breaks the force of concussion, and gives ease to the motion of the joint. The costal cartilages, in forming part of the solid framework of the thorax or chest, impart elasticity to its walls. Hyaline cartilage also enters into the formation of the nose, ear, larynx, and trachea. It strengthens the substance of these parts without making them unduly rigid, maintains their shape, keeps open the passages through them where such exist, and gives attachment to moving muscles and connecting ligaments.

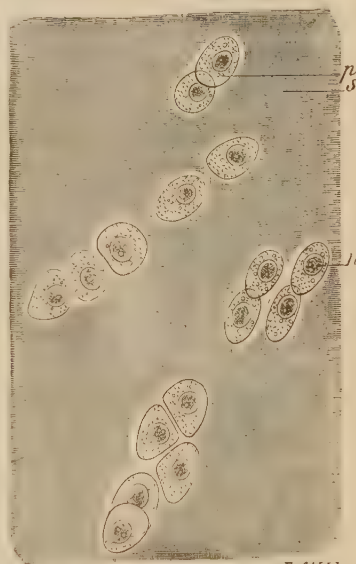


FIG. 26. — ARTICULAR HYALINE CARTILAGE FROM THE FEMUR OF AN OX. *s*, intercellular substance; *p*, protoplasmic cell; *n*, nucleus. (Ranvier.)

White fibro-cartilage. — The intercellular substance is pervaded with bundles of white fibres, between which are scattered cartilage cells. It closely resembles white fibrous tissue.

White fibro-cartilage is found joining bones together, the most familiar instance being the flat, round plates or discs of fibro-cartilage connecting the bones of the spine and the pubic bones. In these cases the part in contact with the bone is always hyaline cartilage, which passes gradually into the fibro-cartilage.

Function. — It serves as a strong, flexible, connecting material between bones and is found wherever great strength combined with a certain amount of rigidity is required.

Yellow, or elastic, fibro-cartilage. — The intercellular substance is pervaded with yellow elastic fibres which form a network. In the meshes of the network the cartilage cells are found.

Yellow, or elastic, fibro-cartilage is found in the epiglottis, cartilages of the larynx, Eustachian tube, and external ear.

Function. — It strengthens and maintains the shape of these organs, and yet allows of a certain amount of elasticity.

Cartilage is not supplied with nerves, and very rarely with blood-vessels. Being so meagrely supplied with blood, the vital processes in cartilage are very slow, and when a portion of it is absorbed in disease or removed by the knife, it is regenerated very slowly. A wound in cartilage is usually healed by connective tissue proper, which may or may not become gradually transformed into cartilage. Nearly all cartilages receive their nourishment from the *perichondrium,* a moderately vascular fibrous membrane which covers them.

Bone, or osseous, tissue. — Bone is connective tissue in which the intercellular substance derived from the cells is rendered hard by being impregnated with mineral salts.

The mineral, or earthy, substance which is deposited in bone, and which makes it hard, consists chiefly of phosphate of calcium, with about a fifth part of carbonate of calcium, and a small portion of other salts.

The organic, or soft, matter consists chiefly of blood-vessels and connective tissue, and may be almost entirely resolved into gelatine by boiling.

It is possible to separate each of these substances. The mineral matter may be removed by soaking a bone in dilute acid for several days. The result will be a tough, flexible, elastic substance, consisting only of organic matter. The shape of the bone will be preserved, but the specimen will be so free from stiffness that it may be tied in a knot.

The organic matter may be driven off by heat. As before, the shape of the bone will be preserved. The specimen will consist only of mineral matter, will appear white, rigid, and so brittle it can be crushed between the fingers.

Amount of organic and inorganic matter. — The comparative amount of organic and inorganic matter found in bone is dependent on the age of the individual. In the fœtus the tissues that later become bone are either fibrous or cartilaginous. By absorption of mineral substances from the blood, these tissues gradually become ossified. Thus it follows that in youth the organic matter is in excess. In adult life the organic matter constitutes about one-third of the weight of the bone, and the inorganic

matter two-thirds. In old age the amount of inorganic matter is increased.

Fracture. — The term *fracture* is applied to the breaking of a bone. As a result of the greater amount of organic matter in the bones of children, they are flexible, bend easily, and do not break readily. In some cases the bone bends like a bough of green wood. Some of the fibres may break, but not the whole bone, hence the name *green-stick fracture.* It is also true that the greater amount of inorganic matter in the bones of the aged render the bones more brittle, so that they break easily and heal with difficulty.

Rachitis or Rickets. — In the disease called rickets, quite common among poorly nourished children, there is not sufficient mineral matter, so that the bones are flexible, bend easily, and may be permanently mis-shapen.

Structure of Bone. — On sawing a bone it will be seen that in some parts it is open and spongy, whilst in others it is dense and close in texture, appearing like ivory. We thus distinguish two forms of bony tissue: —

(1) *The cancellated, or spongy.*

(2) *The dense, or compact.*

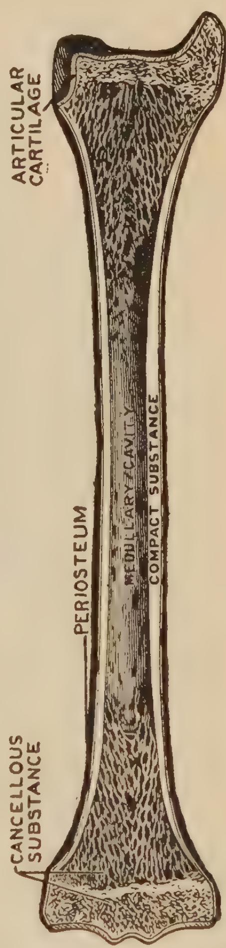


FIG. 27. — VERTICAL SECTION OF A LONG BONE. (Gerrish.)

On closer examination, it will be seen that the bony matter is everywhere porous, and that the difference between the two varieties of tissue arises from the fact that the compact tissue has fewer spaces and more solid matter between them, while the cancellated has larger cavities and more slender intervening bony partitions. In all bones the compact tissue is the stronger; it lies on the surface of the bone and forms an outer shell or crust, whilst the lighter, spongy tissue is contained within. The shafts of the long bones are made up almost entirely of the compact substance, except that they are

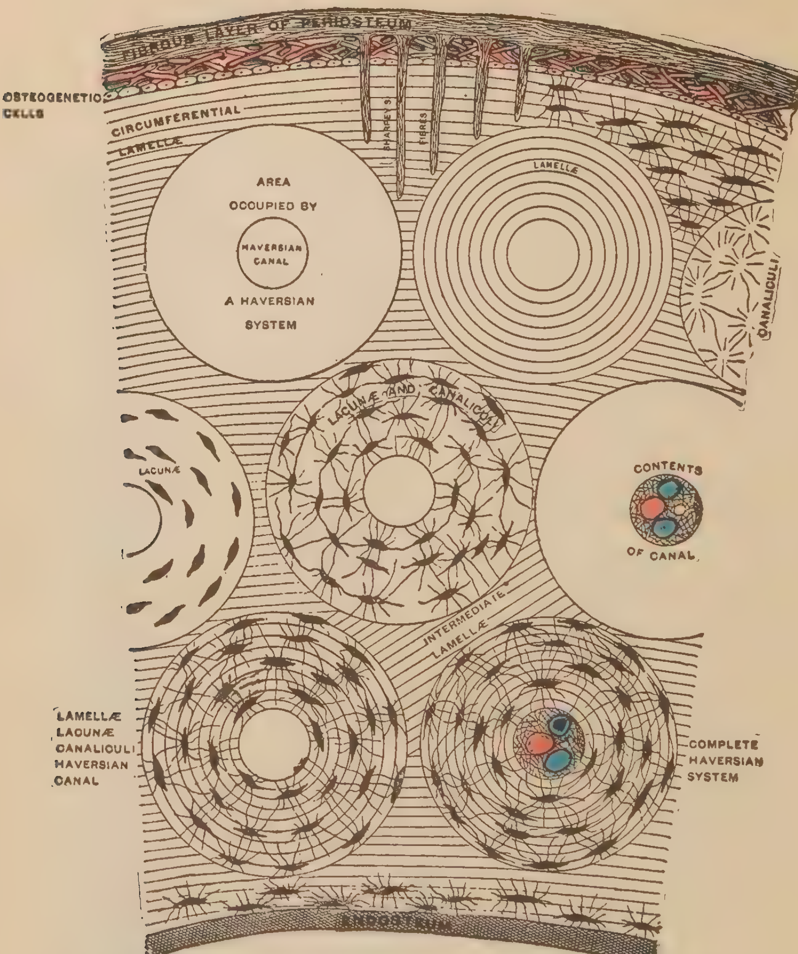


FIG. 28. — DIAGRAM OF THE STRUCTURE OF OSSEOUS TISSUE. A small part of a transverse section of the shaft of a long bone is shown. At the uppermost part is the periosteum covering the outside of the bone; at the lowermost part is the endosteum lining the marrow cavity. Between these is the compact tissue consisting largely of a series of Haversian systems, each being circular in outline and perforated by a central canal. In the first one is shown only the area occupied by a system; in the second is seen the concentric arrangement of the lamellæ; in the others, respectively, canaliculi; lacunæ; lacunæ and canaliculi; the contents of the canal, artery, vein, lymphatic, and areolar tissue; lamellæ, lacunæ, and canaliculi; and finally all of the structures composing a complete system. Between the systems are circumferential and intermediate lamellæ, only a few of which are represented as lodging lacunæ, though it is to be understood that lacunæ are in all parts. The periosteum is seen to be made up of a fibrous layer and a vascular layer, and to have upon its attached surface a stratum of cells. From the fibrous layer project inward the rivet-like fibres of Sharpey. (Gerrish.)

hollowed out to form a central canal, — the medullary canal, — which has a fibrous lining called *endosteum,* and contains marrow.

The hard substance of both varieties is arranged in bundles of bony fibres, or *lamellæ* (layers).

Cancellated bone. — In cancellated bone the lamellæ join and meet together so as to form a structure resembling lattice-work (*cancelli*), whence this tissue receives its name. In the interstices of this kind of bone we find the blood-vessels supported by the marrow.

Compact bone. — In compact bone the lamellæ are usually arranged in rings around canals, — Haversian canals, — which carry

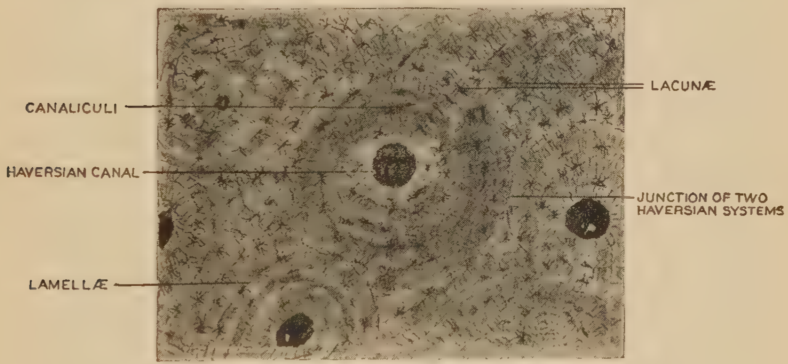


Fig. 29. — Transverse Section of Osseous Tissue.

blood-vessels in a longitudinal direction through the bones. The canals branch freely from system to system, carrying the blood-vessels with them. Between the lamellæ are branched cells which lie in cell-spaces, or cavities, called *lacunæ* (little lakes), and running out in a wheel-like or radial direction from each lacuna are numerous tiny wavy canals called *canaliculi,* connecting one lacuna with another, and forming a system of minute channels which communicate with each other and with the Haversian canal. This constitutes an *Haversian System,* so named from Havers, a celebrated anatomist. Bone is composed of countless such systems. The spaces between these systems are filled by lamellæ arranged at irregular angles.

Marrow. — Marrow consists of fibrous tissue with blood-vessels, fat cells, marrow-cells, and red corpuscles. There are two distinct kinds of marrow, yellow and red. Yellow marrow contains a

larger per cent of fat, and is found in the medullary canals of the long bones. Red marrow contains less fat, but is highly vascular and occupies the spaces in cancellous bone. The function of marrow is (1) to support the blood-vessels, lymphatics, and nerves; (2) to serve as a source of nourishment for bone; and (3) as a location for the formation of red cells. (See page 157.)

Periosteum. — All bones are covered, except at the joints, by a vascular fibrous membrane, the periosteum (around the bone). It consists of an outer fibrous layer and an inner vascular layer. The attachment of the periosteum to bone is rendered firmer by inward prolongations of the fibrous layer called the *fibres of Sharpey*.

Blood-vessels. — Unlike cartilage, the bones are plentifully supplied with blood. If we strip the periosteum from a fresh bone, we see many bleeding points representing the canals (Volkman's) through which the blood-vessels enter and leave the bone. These blood-vessels proceed from the periosteum to join the system of Haversian canals. Around the Haversian canals the lamellæ are disposed, while lying between them, arranged in circles, are found the lacunæ, which contain the bone-cells. Running from one lacuna to another in a radial direction through the lamellæ towards the centre are the canaliculi. Following this scheme, it will be seen that the innermost canaliculi run into the Haversian canals, and thus is established a direct communication between the blood in these canals and the cells in the lacunæ connected with and surrounding each Haversian canal. In this way the whole substance of the bone is penetrated by intercommunicating channels, and the nutrient matters and mineral salts from the blood in the Haversian canals can find their way to every part.

Function of periosteum in growth of bone. — In the embryo the foundation of the skeleton is laid in cartilage, or in primitive connective tissue, ossification of the bones occurring later. The hardening or ossification of the bones is accomplished by the penetration of blood-vessels and bone-cells, called osteoblasts, from the periosteum. As they penetrate into the cartilaginous or membranous models, they absorb the cartilage and connective tissue and deposit the true bone tissue at various points until they form the particular bony structure with which we are familiar.

Regeneration of bone. — A fracture is usually accompanied by injury to the periosteum and tissues. This results in inflam-

mation, which means that an increased amount of blood is sent to the part. The plasma and white blood corpuscles from the blood exude into the tissues and form a viscid substance, which sticks the ends of the bone together, and is called *callus*. Usually bone-cells from the periosteum and lime salts are gradually deposited in the callus, which eventually becomes hardened and forms new bone. Occasionally the callus does not ossify and a condition known as *fibrous union* results. The periosteum is largely concerned in this process of repair; for if a portion of the periosteum be stripped off, the subjacent bone will be liable to die, while if a large part or the whole of a bone be removed, and the periosteum at the same time left intact, the bone will wholly or in a great measure be regenerated.

SUMMARY

CONNECTIVE TISSUE — A tissue of cells with a great deal of intercellular substance, which is derived from the cells.

Reasons for classification
1. Resemble each other in function.
2. Resemble each other in origin.[1]
3. Resemble each other in structure.

Classification

Areolar,	Reticular,
Fibrous,	Neuroglia,
Elastic,	Cartilage,
Adipose,	Bone.

Areolar tissue. — Formed by interlacing of wavy bundles of white fibres and some straight elastic fibres with cells lying in the spaces.

Fibrous tissue. — Formed of wavy bundles of white fibres only, with cells in rows between bundles. Very strong and tough but pliant.

Elastic tissue. — Formed of yellow elastic fibres with few bundles of white fibres. It is extensile and elastic.

Function
- **Areolar tissue** connects, insulates, forms protecting sheaths, and is continuous throughout the whole body.
- **Fibrous tissue** is found in form of ligaments, tendons, aponeuroses, protecting sheaths, and fasciæ.
- **Elastic tissue** serves same purpose as India rubber. Saves wear and tear of muscles. Found in *ligamenta flava*, blood-vessels, air-tubes, vocal cords, lungs, and larynx.

Adipose tissue. — Modification of areolar tissue, with cells enlarged and filled with fat. Distribution quite general but not uniform.

Function
1. Forms a reserve fund for the production of energy.
2. Prevents the too rapid loss of heat.
3. Serves to protect and support delicate organs.

[1] With one exception, neuroglia.

Reticular tissue. — Network of white fibres with few yellow fibres. Cells wrapped around fibres.

Lymphoid tissue. — Reticular tissue with meshes of network occupied by lymph corpuscles.

Function. — Reticular tissue forms a fine framework in many organs, *e.g.*, muscles. — Lymphoid tissue forms the structure of the spleen and lymph-nodes. Also enters into composition of glands and mucous membranes.

Neuroglia. — Consists of cells that give off processes which form a network.

Function. — Forms a supporting framework for nerve tissue.

Cartilage. — Cartilage or gristle is a bluish white tissue, firm and elastic, covered and nourished by perichondrium.

Varieties
1. **Hyaline cartilage** — Articular, Costal — Skeletal.
2. **White fibro-cartilage.**
3. **Yellow fibro-cartilage.**

Hyaline — Small number of cells in an abundant quantity of intercellular substance. Found as articular cartilage, covering ends of bones in joints. Found as costal cartilage, connecting ribs and sternum, or one rib with another.

White Fibro — Intercellular substance pervaded with white fibres. Resembles fibrous tissue. Found between spinal and pubic bones.

Yellow Fibro — Intercellular substance pervaded with network of yellow elastic fibres. Found in parts of throat and ear.

Function	Hyaline cartilage	Serves as cushions for ends of bones. Makes a flexible connection between the ribs and the sternum, or between one rib and another. Strengthens and maintains shape of certain organs without rigidity.
	White fibro-cartilage	Serves as strong, flexible, connecting material between bones.
	Yellow fibro-cartilage	Strengthens and maintains shape of certain organs, and yet allows of certain amount of elasticity.

Bone, or osseous, tissue. — Bone is connective tissue in which the intercellular substance derived from the cells is rendered hard by being impregnated with mineral salts.

Composition	Mineral matter	Calcium phosphate. Calcium carbonate. Small portion of other salts.
	Organic matter	Blood-vessels. Connective tissue. Marrow.

BONE OR OSSEOUS TISSUE

- **Varieties**
  - Cancellated or spongy.
  - Dense or compact like ivory.
- **Canals**
  - Medullary — Yellow marrow.
  - Haversian
    - Blood-vessels.
    - Lymphatics.
- **Haversian system**
  - Haversian canals, branch freely and connect system to system.
  - Lamellæ — bony fibres arranged in rings around Haversian canals.
  - Lacunæ — small spaces between lamellæ occupied by bone-cells.
  - Canaliculi — canals which radiate from lacunæ to the Haversian canals.
- **Endosteum** — A fibrous membrane that lines the medullary canal.
- **Marrow**
  - **Consists of**
    - Fibrous tissue, blood-vessels, fat cells, marrow cells, and red corpuscles.
  - **Varieties**
    - Yellow — found in medullary canals of long bones.
    - Red — occupies spaces in cancellous bone.
  - **Function**
    1. Supports blood-vessels, lymphatics, and nerves.
    2. Serves as a source of nourishment for bone.
    3. Serves as location for formation of red corpuscles.
- **Periosteum** — A vascular fibrous membrane that covers the bones and serves to nourish them. Important in reunion of broken bone and growth of new bone.
- **Fibres of Sharpey** — Inward prolongations of periosteum.

CHAPTER V

THE SKELETON. — CLASSIFICATION OF BONES; DIVISIONS OF THE SKELETON; BONES OF THE CRANIUM; BONES OF THE FACE; BONES OF THE TRUNK; BONES OF THE UPPER EXTREMITIES; BONES OF THE LOWER EXTREMITIES

Function. — The **bones** are the principal organs of support, and the passive instruments of locomotion. Connected together in the skeleton, they form a framework of hard material, affording attachment to the soft parts, maintaining them in their due position, sheltering such as are of delicate structure, giving stability to the whole fabric, and preserving its shape.

The entire skeleton in the adult consists of two hundred and six named bones. These are: —

Cranium	8	
Face	14	
Ear { Malleus 2, Incus 2, Stapes 2 }	6	
Hyoid	1	206
The spine, or vertebral column (sacrum and coccyx included)	26	
Sternum and ribs	25	
Upper extremities	64	
Lower extremities	62	

In this enumeration the sesamoid[1] bones, which are found embedded in tendons covering the bones of the knee, hand, and foot, are not included.

CLASSIFICATION

The bones may be divided, according to their shape, into four classes: 1. **Long**, 2. **Short**, 3. **Flat**, and 4. **Irregular**.

Long bones. — A long bone consists of a shaft and two extremities. The shaft is formed mainly of compact tissue, this compact

[1] Ses′amoid [from the Greek *sēsamon*, a "seed of the sesamum," and *eidos*, "form," "resemblance"], resembling a grain of sesamum.

tissue being thickest in the middle, where the bone is most slender and the strain greatest, and it is hollowed out in the interior to form the *medullary canal.* (See Fig. 27.) The extremities are made up of cancellated tissue with only a thin coating of compact

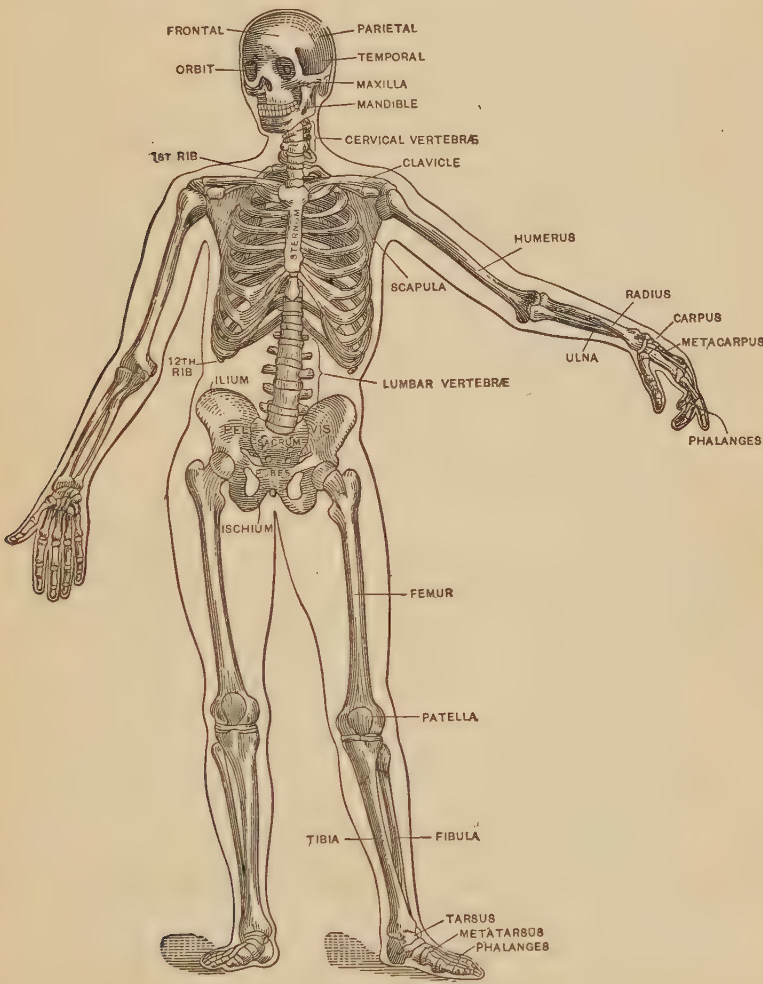


FIG. 30. — THE HUMAN SKELETON. (Morrow.)

substance, and are more or less expanded for greater convenience of mutual connection, and to afford a broad surface for muscular attachment. All long bones are more or less curved, which gives them greater strength. The long bones are as follows: —

2 Clavicle	2 Tibia
2 Humerus	2 Fibula
2 Radius	10 Metacarpals
2 Ulna	10 Metatarsals
2 Femur	56 Phalanges

Short bones. — The short bones are small pieces of bone irregularly shaped. Their texture is spongy throughout, excepting at their surface, where there is a thin crust of compact substance. The short bones are the sixteen bones of the carpus, the fourteen bones of the tarsus, and the two patellæ.

Flat bones. — Where the principal requirement is either extensive protection or the provision of broad surfaces for muscular attachment, the bony tissue expands into broad or elongated flat plates which are composed of two thin layers of compact tissue, enclosing between them a variable quantity of cancellous tissue. The flat bones are as follows: —

1 Occipital	2 Lacrimal
2 Parietal	2 Scapula
1 Frontal	1 Sternum
2 Nasal	24 Ribs
1 Vomer	2 Hip bones

Irregular bones. — The irregular bones are those which, on account of their peculiar shape, cannot be grouped under either of the preceding heads. The irregular bones are as follows: —

24 Vertebræ	2 Malar
1 Sacrum	2 Maxillæ
1 Coccyx	1 Mandible
2 Temporal	2 Palate
1 Sphenoid	2 Inferior turbinated
1 Ethmoid	1 Hyoid

The bones of the ear are so small that they are described as *ossicles* and do not fit in any of these groups.

Processes and depressions. — If the surface of any bone is examined, certain projections and depressions are seen. The projections are called *processes*. The depressions are called *fossæ* or *cavities*, and either a qualifying adjective is used to describe them, or a special name given to them. Processes and depressions are classified as: 1. **Articular**, 2. **Non-articular**. The articular are provided for the mutual connection of bones to form joints. The

non-articular serve for the attachment of ligaments and muscles. The following terms are used: —

Process. — Any marked bony prominence.

Tuberosity. — A large process.

Tubercle. — A small process.

Spinous. — A sharp, slender process.

Crest. — A narrow ridge of bone.

Condyle. — A rounded or knuckle-like process.

Head. — A portion supported on a constricted part or neck.

Fossa. — A depression in or upon a bone.

Cavities. — The terms *sinus*[1] and *antrum* are applied to cavities within certain bones.

Meatus or Canal. — A long tube-like passageway.

Fissure. — A narrow slit.

Foramen. — A hole or orifice through which blood-vessels, nerves, and ligaments are transmitted.

DIVISIONS OF THE SKELETON

In taking up the various divisions of the skeleton, we will consider it as consisting of —

1. Head or skull	Cranium. Face.
2. Hyoid.	
3. Trunk	Vertebræ. Sternum. Ribs.
4. Upper extremities.	
5. Lower extremities.	

The head or skull. — The head or skull rests upon the spinal column, and is formed by the union of the cranial and facial bones. It is divisible into — 1. **Cranium,** or **brain** case, and 2. **Anterior region,** or **face.**

BONES OF THE CRANIUM

Occipital	1	8
Parietal	2	
Frontal	1	
Temporal	2	
Ethmoid	1	
Sphenoid	1	

[1] The term "sinus" is also used in surgery to denote a narrow tract leading from the surface down to a cavity.

Occipital bone. — It is situated at the back and base of the skull. At birth the bone consists of four parts, which do not

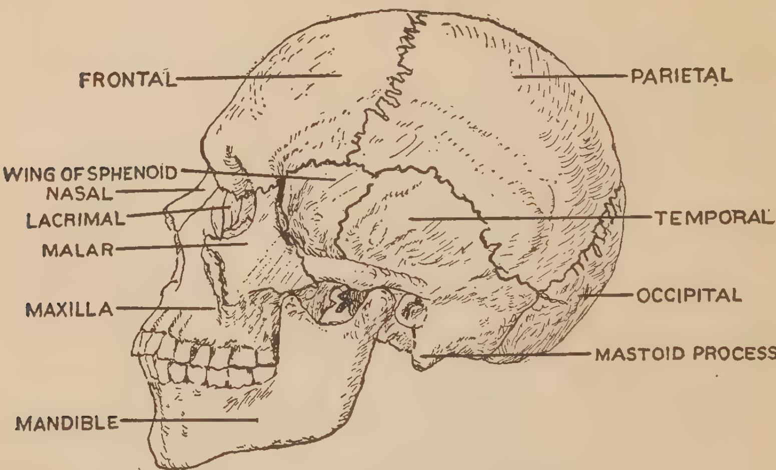


FIG. 31. — SIDE VIEW OF THE SKULL.

unite into a single bone until the sixth year. The internal surface is deeply concave, and presents many eminences and depressions for the reception of parts of the brain. There is a large

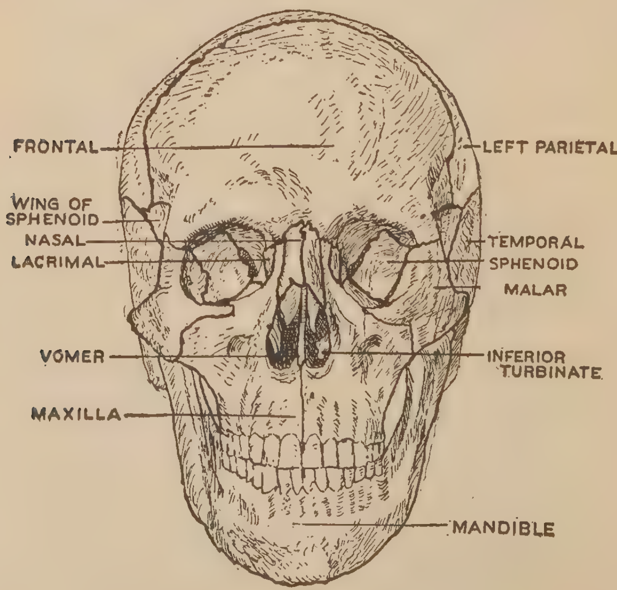


FIG. 32. — FRONT VIEW OF THE SKULL.

hole — the *foramen magnum* — in the inferior portion of the bone, for the transmission of the medulla oblongata (the constricted portion of the brain) where it narrows down to join the spinal

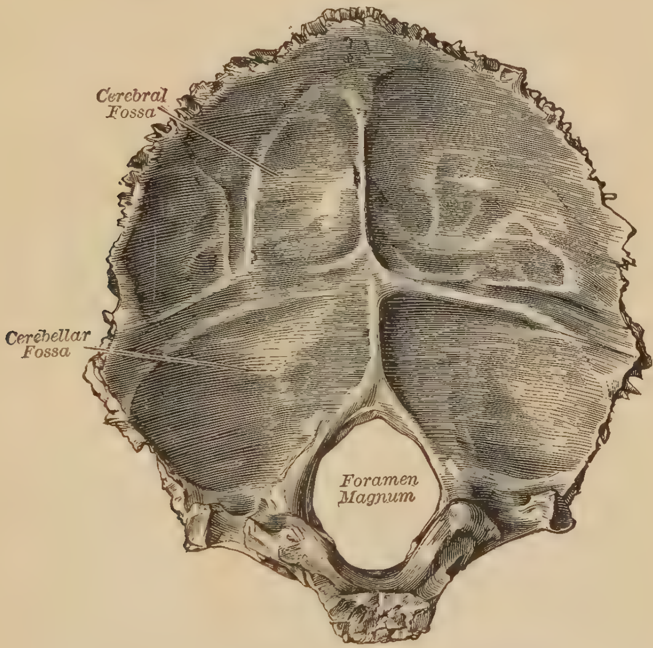


FIG. 33. — OCCIPITAL BONE. Inner surface.

cord. At the sides of the foramen magnum it presents two processes called condyles, which articulate with the first vertebra.

Parietal bones. — The right and left form by their union the greater part of the sides and roof of the skull. The external surface is convex and smooth; the internal surface is concave, and presents eminences and depressions for lodging the convolutions of the brain, and numerous furrows for the ramifications of arteries which supply the dura mater (membrane which covers the brain) with blood.

Frontal bone. — It resembles a cockle shell, and not only forms the forehead, but also enters into the formation of the roof of the orbits, and of the nasal cavity. The arch formed by part of the frontal bone over the eye is sharp and prominent, and is known as the supraorbital margin. Just above the supraorbital margins are hollow spaces called the *frontal sinuses* (see Fig. 40) which are

filled with air and open into the nose. In the upper and outer angle of each orbit are two depressions called lacrimal fossæ for the reception of the glands of the same name, which secrete the tears. At birth the bone consists of two pieces, which afterwards become united along the middle line, by a suture[1] which runs from

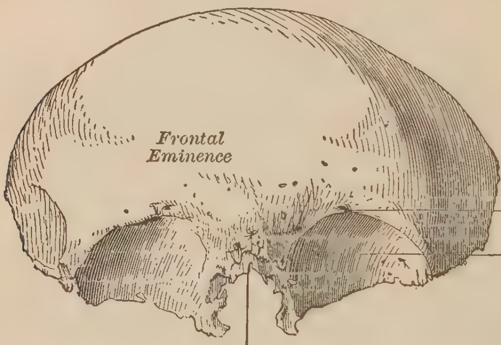


FIG. 34. — FRONTAL BONE.

the vertex of the bone to the root of the nose. This suture usually becomes obliterated within a few years after birth, but it occasionally remains throughout life.

Temporal bones. — The right and left are situated at the sides and base of the skull. They are named temporal from the Latin word *tempus*, time, as it is on the temples the hair first becomes gray and thin, and thus shows the ravages of time. The temporal bones are divided into three parts — the hard, dense portion, called *petrous;* a thin and expanded scale-like portion, called *squamous;* and a mastoid portion, which is prolonged downward and forms the *mastoid process*. This process is filled with a number of connected cancellous spaces, containing air, and called **mastoid cells.**[2] They communicate with the cavity of the middle ear. The condition known as mastoiditis means inflammation of the lining of these cells.

The internal ear, the essential part of the organ of hearing, is contained in a series of cavities, channelled out of the substance

[1] See Figs. 66 and 67.

[2] Cells. — The student must bear in mind that the word cell is used with two different meanings in anatomy. Histologically speaking, the word "cell" refers to one of the component units of the body, such as an "epithelial cell" or "nerve cell."

In connection with the use of the words "mastoid cells" in the text, the word "cells" refers to tiny enclosed hollow chambers.

of the petrous portion. Between the squamous and petrous portions is a socket, called the *glenoid fossa,* for the reception of the condyle of the lower jaw.

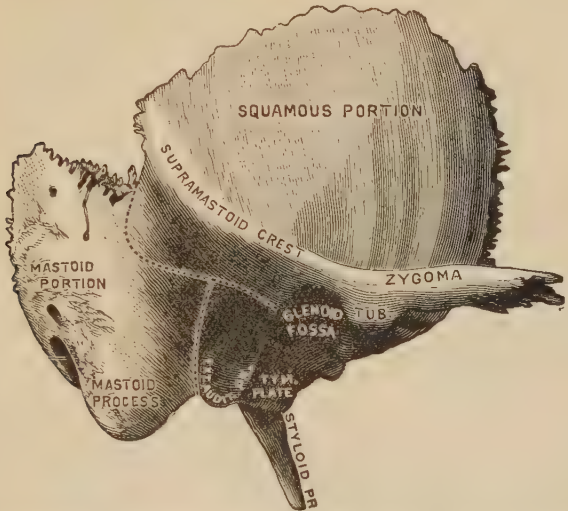


FIG. 35. — THE RIGHT TEMPORAL BONE. Outer surface. The dotted lines indicate the lines of suture between squamous, mastoid, and petrous portions. (Gerrish.)

Ethmoid bone. — It is an exceedingly light cancellous bone that forms part of the orbits, nasal fossæ, and base of the cranium. It consists of a horizontal plate, a vertical plate (see Fig. 36), and

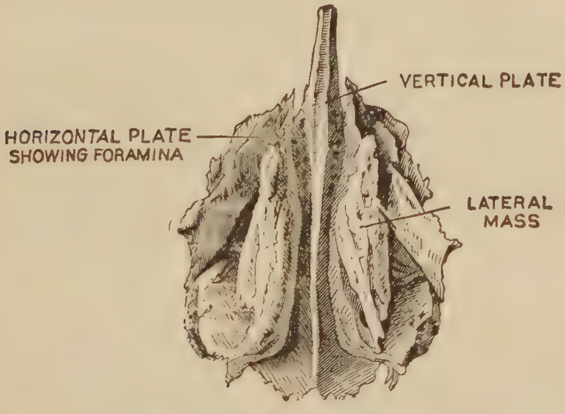


FIG. 36. — ETHMOID BONE. Seen from under surface.

two lateral masses. The horizontal plate forms the roof of the nasal fossæ, and also closes the anterior part of the base of the

cranium. It is pierced by numerous foramina or holes, through which the nerves conveying the sense of smell pass. Descending from the horizontal plate is the vertical plate which helps to form the nasal septum, and on either side the lateral masses help to form the side walls of the nasal fossæ. The lateral masses contain a number of thin-walled cavities called the ethmoidal sinuses, which communicate with the nasal fossæ. Descending from the horizontal plate on either side of the septum are two processes of very thin, cancellous, bony tissue, named the superior and middle turbinated processes. (See Fig. 153.)

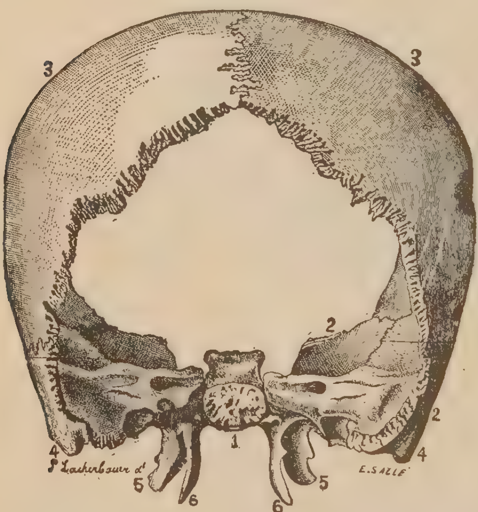


FIG. 37.—PARIETAL, TEMPORAL, AND SPHENOID BONES. Posterior aspect. 1, body of sphenoid bone; 2, 2, greater wings of sphenoid bone; 3, 3, parietal bones; 4, 4, mastoid process of temporal bones; 5, 5, external pterygoid plate; 6, 6, internal pterygoid plate. (Gould's Dictionary.)

Sphenoid bone.—It is situated at the anterior part of the base of the skull and binds the other cranial bones together. It helps to form the cavities of the cranium, orbits, and nasal fossæ. In form it somewhat resembles a bat with extended wings, and is described as consisting of a body, two pairs of wings, and two pterygoid processes. The body is joined to the ethmoid in front and the occipital behind. It contains cavities which are called sphenoidal sinuses. (See Fig. 40.) They communicate with the nasal fossæ.

THE SKULL AS A WHOLE

The cranium is a firm case or covering for the brain. Four of the eight bones which form this bony covering are classed as flat bones. They consist of two layers of compact tissue, the outer one thick and tough, the inner one thinner and more brittle. The cancellated tissue lying between these two layers, or "tables of the skull," is called the *diploë*. The base of the skull is much thicker

and stronger than the walls and roof; it presents a number of openings for the passage of the cranial nerves, blood-vessels, etc.

The bones of the cranium begin to develop at a very early period of fœtal life. Thus, before birth the bones at the top and sides of the skull are separated from each other by membranous tissue in which bone is not yet formed, and being then imperfectly ossified, they are readily *moulded*, and overlap one another more or less during parturition. The spaces at the angles of the bone occupied by the membranous tissue are termed the fontanelles, so named from the pulsations of the brain, which can be seen in some of them and which the early anatomists likened to the rise and fall of water in a fountain. There are six of these fontanelles.

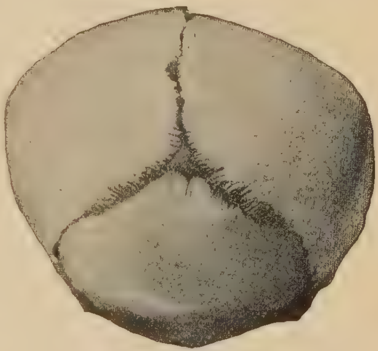


FIG. 38. — SKULL OF NEW-BORN CHILD. To show moulding. (Edgar.)

Anterior fontanelle. — The anterior fontanelle is the largest, and is a lozenge-shaped space between the angles of the two parietal bones and the two segments of the frontal bone. It remains open until the second year, and occasionally persists throughout life. (See Fig. 66.)

Posterior fontanelle. — The posterior fontanelle is much smaller in size, and is a triangular space between the occipital and two parietal bones. This is closed by an extension of the ossifying process a few months after birth. (See Fig. 67.)

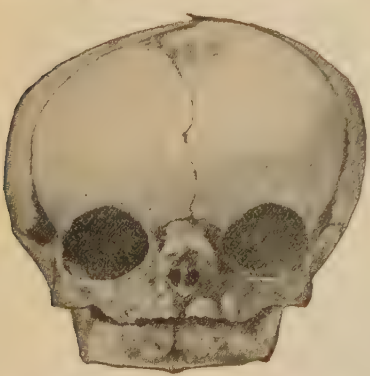


FIG. 39. — SKULL OF NEW-BORN CHILD. To show moulding. (Edgar.)

The other four fontanelles, two on each side of the skull, are placed at the inferior angles of the parietal bones; they are unimportant. Small, irregular ossicles called sutural bones (Wormian bones) are found in the sutures of the head, chiefly near the fontanelles, and often assist in the closure of the fontanelles.

Sinuses of the head. — Four sinuses communicate with each nasal cavity: the frontal, ethmoidal, sphenoidal, and maxillary or antrum of Highmore. The mucous membrane which lines the nose also lines all of these sinuses, and inflammation of this membrane may extend into any of them and cause *sinusitis.* (See Fig. 97.)

BONES OF THE FACE

Nasal	2	14
Vomer	1	
Inf. Turbinated	2	
Lacrimal	2	
Malar	2	
Palate	2	
Maxillæ	2	
Mandible	1	

Nasal bones. — They are two small oblong bones placed side by side at the middle and upper part of the face, forming by their junction "the bridge" of the nose. (See Fig. 31.)

Vomer. — It is a single bone placed at the lower and back part of the nasal cavity, and forms part of the central septum of the

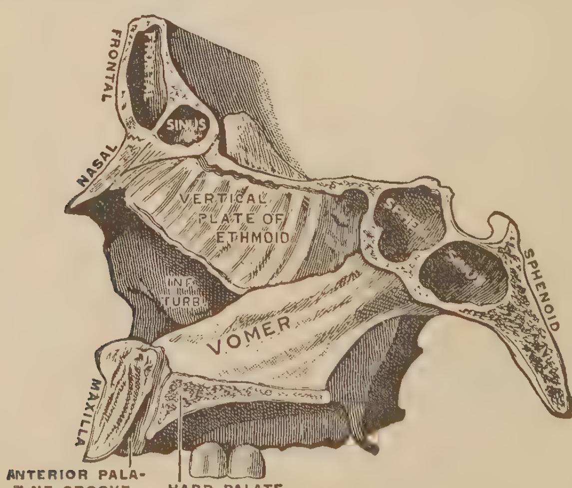


FIG. 40. — SAGITTAL SECTION OF FACE, A LITTLE TO THE LEFT OF THE MIDDLE LINE, SHOWING THE VOMER AND ITS RELATIONS. (Gerrish.)

nasal fossæ. It is thin, and shaped somewhat like a ploughshare, but varies in different individuals, being frequently bent to one or the other side, thus making the nasal chambers of unequal size.

Inferior turbinated bones. — They are situated in the nostril, on the outer wall of each side. Each consists of a layer of thin, cancellous bone, curled upon itself like a scroll; hence its name, "turbinated." They are below the superior and middle turbinated processes of the ethmoid bone. Abnormal conditions of these bones and the membranes covering them cause some of the more common nasal diseases. (See Fig. 153.)

FIG. 41. — LACRIMAL BONE.

Lacrimal bones. — Are the smallest and most fragile bones of the face. They are situated at the front part of the inner wall of the orbit, and somewhat resemble a finger-nail in form, thinness, and size. They are named lacrimal because they contain part of the canal through which the tear duct runs.

Malar, or yoke bone. — Forms the prominence of the cheek, and part of the outer wall and floor of the orbit. (See Figs. 31 and 32.) A prominent spine of bone projects backward from the body of the malar, and articulates by its free extremity with the corresponding spine projecting forward from the temporal bone, thus making the two members of the true arch known as the zygomatic arch. (See Fig. 35.)

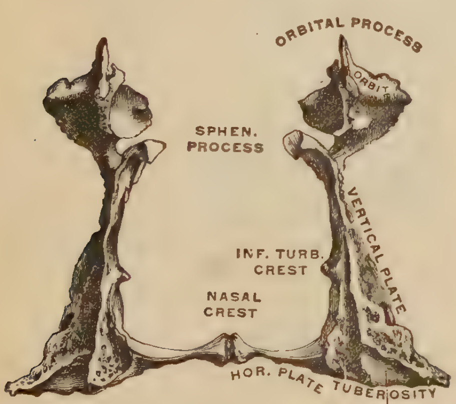


FIG. 42. — THE TWO PALATE BONES IN THEIR NATURAL POSITION. Dorsal view. (Gerrish.)

Palate bones. — They are shaped like an "L," and form (1) the back part of the roof of the mouth; (2) part of the floor and outer wall of the nasal fossæ; (3) a very small portion of the floor of the orbit.

Maxillæ, or upper jaw-bones, also known as superior maxillary. — The maxillæ are two in number (right and left) and are the principal bones of the face. Before birth these bones usually unite to form one bone. When they fail to do so we have the condition known as *cleft palate*. Each bone assists in forming (1) part of the floor of the orbit, (2) the floor and outer wall

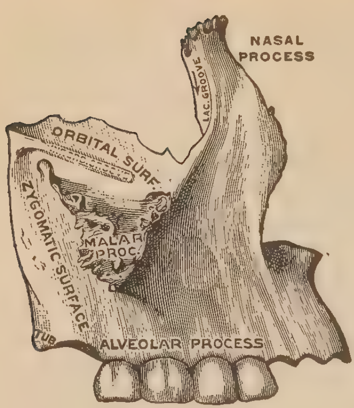


FIG. 43. — THE RIGHT MAXILLA. Outer surface. (Gerrish.)

of the nasal fossæ, (3) the greater part of the roof of the mouth.

That part of the bone which contains the teeth is called the alveolar process, and is excavated into cavities, varying in depth and size according to the size of the teeth they contain. The body of the bone is hollowed out into a large cavity known as the *antrum of Highmore,* which opens into the nose. Abnormal conditions of either the nose or teeth may cause an infection of these antrums.

Mandible, or lower jaw-bone, also known as inferior maxillary. — It is the largest and strongest bone of the face. At birth, it consists of two lateral halves, which join and form one bone during the first or second year. It serves for the reception of the lower teeth, and undergoes several changes in shape during life, owing mainly (1) to the first and second dentition, (2) to the loss of teeth in the aged, and (3) the subsequent absorption of that part of the bone which contained them. It articulates, by its condyles, with the sockets in the temporal bones, which allows for free movement in mastication.

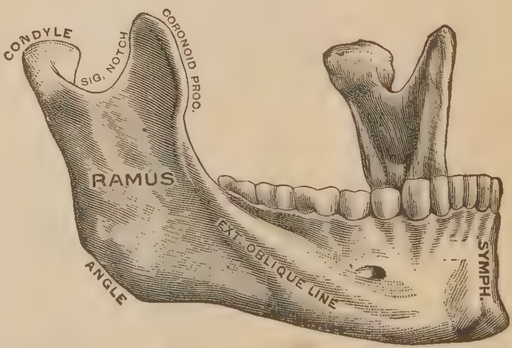


FIG. 44. — THE MANDIBLE. Viewed from the right and a little in front. (Gerrish.)

Hyoid bone (os hyoideum). — Is an isolated U-shaped bone lying in

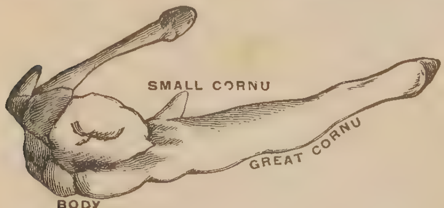


FIG. 45. — THE HYOID BONE. Viewed from the left and in front. (Gerrish.)

front of the throat, just above the laryngeal prominence (Adam's apple). It supports the tongue, and gives attachment to some of its numerous muscles.

TRUNK

The bones which enter into the formation of the **trunk** consist of the **vertebræ**, **sternum**, and **ribs**.

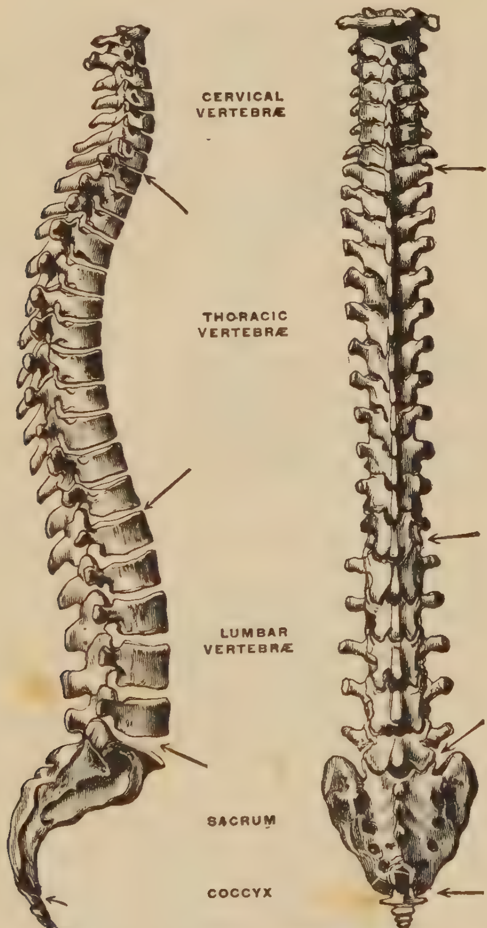


FIG. 46. — THE VERTEBRAL COLUMN. Right lateral view and dorsal view. (Gerrish.)

The vertebral column as a whole. — It is formed of a series of bones called vertebræ, and in a man of average height is about twenty-eight inches long. In youth the vertebræ are thirty-

three in number, and according to the position they occupy are named: —

Cervical, in the neck	7	}	True vertebræ.
Thoracic, in the thorax	12	}	
Lumbar, in the loins	5	}	
Sacral, in the pelvis	5	}	False vertebræ.
Coccygeal, in the pelvis	4	}	

The vertebræ in the three upper portions of the spine are separate and movable throughout the whole of life, and are known as *true* vertebræ. Those found in the sacral and coccygeal regions are, in the adult, firmly united, so as to form two bones, five entering into the upper bone, or sacrum, and four into the terminal bone of the spine, or coccyx. They are known as *false* vertebræ, and on account of their union the number of vertebræ in the adult is twenty-six.

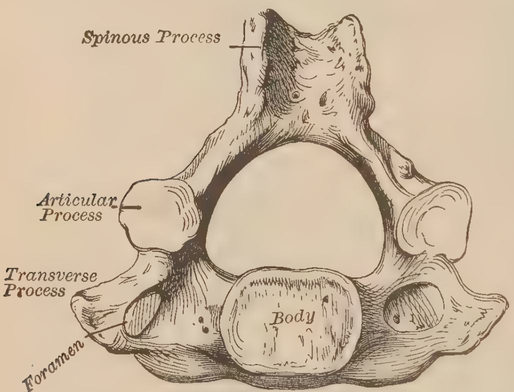


FIG. 47. — A CERVICAL VERTEBRA.

The vertebræ. — Each vertebra consists of two essential parts, an anterior solid portion or body, and a posterior portion or arch. Each arch has seven processes: four articular, two to connect with bone above, two to connect with bone below; two transverse, one at each side, and one spinous process, projecting backward.

Cervical vertebræ. — In the cervical region of the vertebral column the bodies of the vertebræ are smaller than in the thoracic, but the arches are larger. The spinous processes are short, and are often cleft in two, or bifid. The transverse processes are pierced by a foramen for the passage of blood-vessels and nerves.

The first and second cervical vertebræ differ considerably from the rest. The first, or *atlas*, so named from supporting the head has practically no body, and may be described as a bony ring divided into two sections by a transverse ligament. The dorsal

section of this ring contains the spinal cord, and the ventral or front section contains the bony projection which arises from the upper surface of the body of the second cervical vertebra, the *axis* (epistropheus). This bony projection, called the *odontoid* process, forms a pivot, and around this pivot the atlas rotates when the

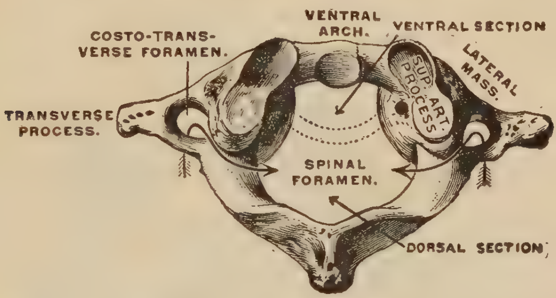


FIG. 48. — THE ATLAS. Viewed from above. (Gerrish.)

head is turned from side to side, carrying the skull, to which it is firmly articulated, with it.

Thoracic vertebræ. — The bodies of the thoracic vertebræ are larger and stronger than those of the cervical; and have a facet or demi-facet for articulation with the vertebral end of a rib.

Lumbar vertebræ. — The bodies of the lumbar vertebræ are the largest and heaviest in the whole spine.

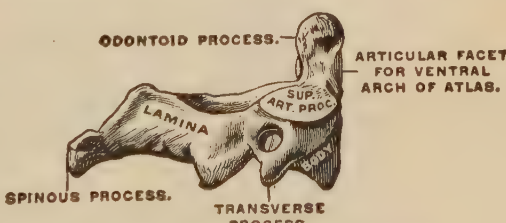


FIG. 49. — THE AXIS (EPISTROPHEUS). Its right side. (Gerrish.)

Structure of vertebral column. — The bodies of the vertebræ are piled one upon another, forming a strong, solid pillar, for the support of the cranium and trunk, the arches forming a hollow cylinder behind for the protection of the spinal cord. Viewed from the side, it presents four curves which are alternately convex and concave. The two concave ones are called primary curves because they exist in fœtal life and are designed for the accommodation of viscera. The other two are called secondary or compensatory curves because they enable the child to assume the erect attitude.

The different vertebræ are connected (1) by means of the articular processes, (2) by disks of intervertebral fibro-cartilage placed between the vertebral bodies, and (3) by broad thin ligaments called the *ligamenta flava* which connect the transverse processes. The spinal curves confer a considerable amount of

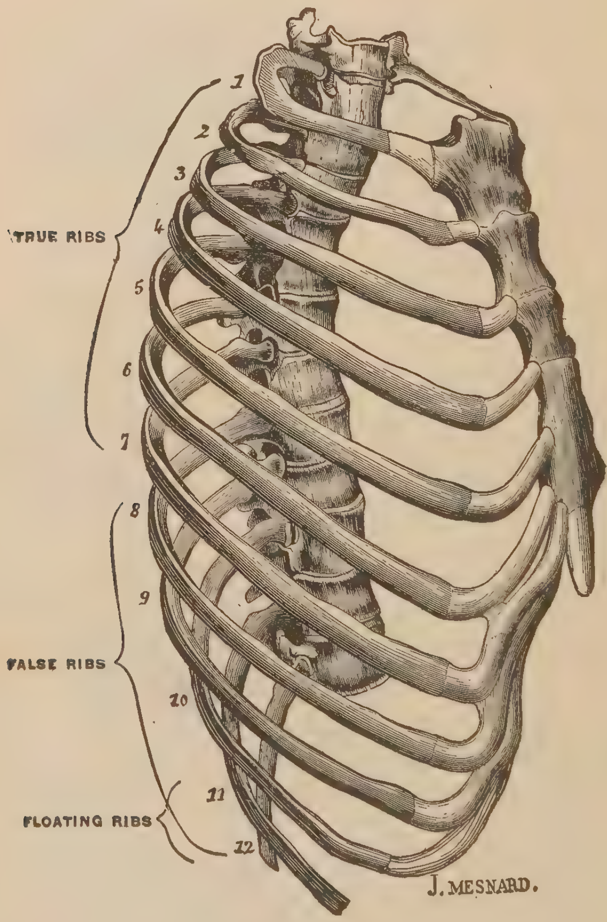


Fig. 50.—Thorax.

springiness and strength upon the spinal column, which would be lacking were it straight, and the elasticity is further increased by the ligamenta flava, and the discs of fibro-cartilage. These discs or pads also mitigate the effects of concussion arising from falls or blows, and allow of a certain amount of motion between

the vertebræ. The amount of motion permitted is greatest in the cervical region.

Abnormal conditions. — As a result of injury or disease the normal curves may become exaggerated and are then spoken of as *curvatures*. Curvatures may be lateral, dorsal, or ventral.

It occasionally happens that the arch of one of the vertebræ does not develop properly, and as a result the membranes and fluid of the spinal cord will protrude, forming a tumor upon the child's back. This condition is called *spina bifida*.

Sacrum (os sacrum). — The sacrum is formed by the union of the five sacral vertebræ. It is a large triangular bone situated like a wedge between the coxal bones, and is curved upon itself in such a way as to give increased capacity to the pelvic cavity.

Coccyx (os coccygis). — The coccyx is usually formed of four small segments of bone, and is the most rudimentary part of the vertebral column.

THORAX

The thorax is an elongated bony cage formed by the sternum and costal cartilages in front, the twelve ribs on each side, and the bodies of the twelve thoracic vertebræ behind. It contains and protects the principal organs of respiration and circulation.

Sternum, or breast bone. — It is a flat, narrow bone about six inches long, situated in the median line in the front of the chest, and may be likened to a short, flat sword. It consists of three portions. The upper part is termed the handle, or manubrium; the middle and largest piece is termed the body, or gladiolus; the inferior portion is termed the ensiform, or the xiphoid process. On both sides of the upper and middle pieces are notches for the recep-

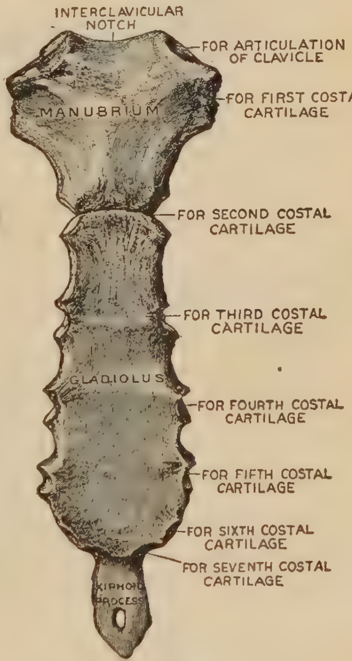


FIG. 51. — THE STERNUM. Ventral aspect. (Gerrish.)

tion of the sternal ends of the costal cartilages. The ensiform or xiphoid process is cartilaginous in structure in early life, but is more or less ossified at the upper part in the adult; it has no ribs attached to it, but affords attachment for some of the abdominal muscles.

Ribs (costæ). — The ribs, twenty-four in number, are situated twelve on each side of the thoracic cavity. They are all connected with the thoracic vertebræ at the back, and the first seven pairs are connected with the sternum in front through the intervention of the costal cartilages. These first seven pairs are called, from their attachment, the *true ribs*. The remaining five pairs are termed *false ribs*. Of these, the upper three,

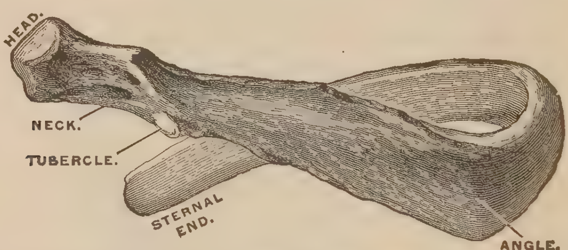


Fig. 52. — The Eighth Rib of the Right Side. Viewed from behind. (Gerrish.)

eighth, ninth, and tenth, are attached in front to the costal cartilages of the next rib above. The two lowest being unattached in front, are termed *floating ribs*.

The convexity of the ribs is turned outward so as to give roundness to the sides of the chest and increase the size of its cavity; each rib slopes downward from its vertebral attachment, so that its sternal end is considerably lower than its dorsal, and the lower border is grooved for the accommodation of the intercostal nerves and blood-vessels. The spaces left between the ribs are called the intercostal spaces.

BONES OF THE UPPER EXTREMITIES

Clavicle (clavicula, or collar bone)	2	64
Scapula (shoulder blade)	2	
Humerus (arm)	2	
Ulna — 2, Radius — 2 (forearm)	4	
Carpus (wrist)	16	
Metacarpus (palm of hand)	10	
Phalanges (fingers)	28	

Clavicle, or collar bone. — It is a long bone, placed horizontally above the thorax. It articulates with the sternum by its inner extremity, which is called the sternal extremity. Its outer or acromial extremity articulates with the scapula. In the female, the clavicle is generally less curved, smoother, shorter, and more

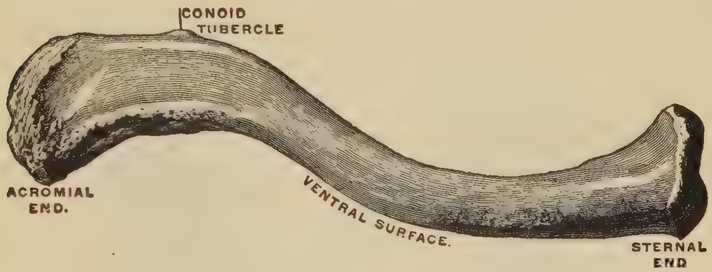


FIG. 53. — THE RIGHT CLAVICLE. Upper surface. (Gerrish.)

slender than in the male. In those persons who perform considerable manual labor, which brings into constant action the muscles connected with this bone, it acquires considerable bulk.

Scapula, or shoulder blade. — It is a large, flat bone, triangular in shape, placed between the second and eighth ribs on the back part of the thorax. It is unevenly divided on its dorsal surface

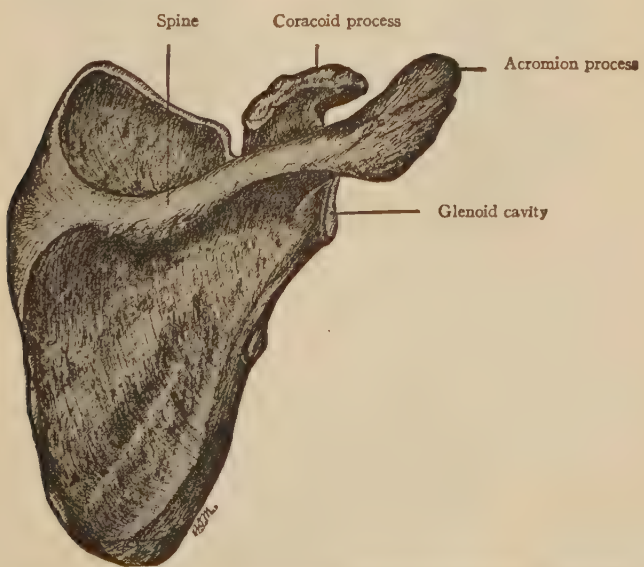


FIG. 54. — THE RIGHT SCAPULA, OR SHOULDER BLADE. (Morrow.)

by a very prominent ridge, the spine of the scapula, which terminates in a large triangular projection called the *acromion process* or summit of the shoulder. Below the acromion process, at the head of the shoulder blade, is a shallow socket, the *glenoid cavity*, which receives the head of the humerus.

Humerus, or arm bone. — The humerus is the longest bone of the upper limb. The upper extremity of the bone consists of a

FIG. 55. — THE LEFT HUMERUS, OR ARM BONE. (Morrow.)

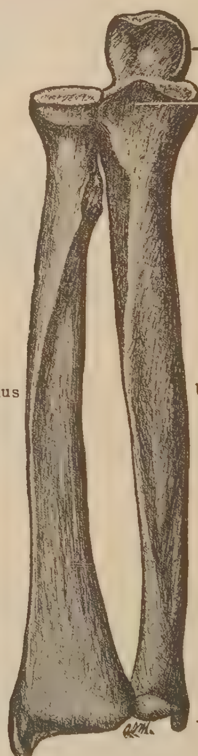


FIG. 56. — THE BONES OF THE RIGHT FOREARM. Anterior view. (Morrow.)

rounded head joined to the shaft by a constricted neck, and of two eminences called the larger and smaller tubercles, also known as tuberosities. The head articulates with the glenoid cavity of the scapula. The constricted neck above the tubercles is called the anatomical neck, and that below the tubercles, the surgical neck, because it is so often fractured. The lower extremity of

the bone is flattened from before backward into a broad articular surface called the trochlea which is divided by a slight ridge so that it ends in two condyles by means of which it articulates with the radius and ulna.

Ulna, or elbow bone. — It is placed at the inner side (little finger side) of the forearm, parallel with the radius. Its upper extremity presents for examination two large curved processes and two concave cavities; the larger process forms the head of the elbow, and is called the olecranon process. The smaller process on the front surface is termed the coronoid, and the trochlea of the humerus fits into the cavity — the great sigmoid cavity — between these two processes. The lesser sigmoid cavity is on the outer side of the coronoid, and receives the head of the radius. The lower extremity of the ulna is of small size and ends in two prominences; the outer one, called the head, articulates with the radius; the inner one, named the styloid process, serves for the attachment of ligaments from the wrist; but the ulna is excluded from the wrist by a piece of fibro-cartilage.

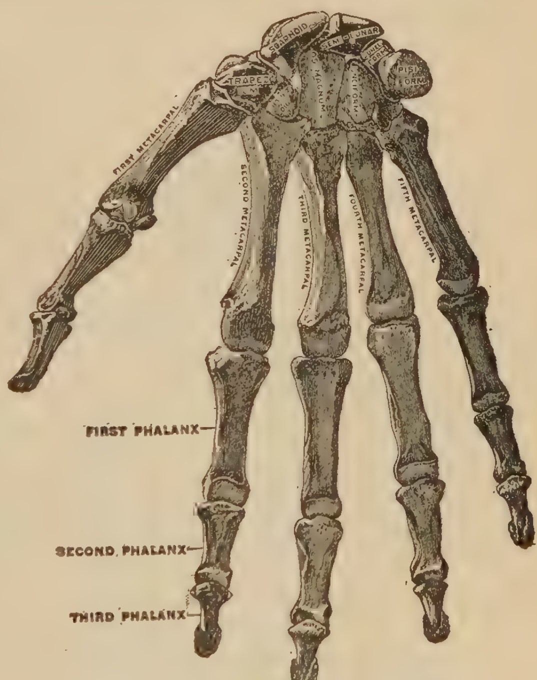


FIG. 57. — THE BONES OF THE RIGHT HAND. Palmar aspect. (Gerrish.)

Radius. — It is situated on the outer side of the forearm. The upper end is small and rounded, with a shallow depression on its upper surface for articulation with the humerus, and a prominent ridge about it, like the head of a nail, by means of which it

rotates within the lesser sigmoid cavity of the ulna. The lower end of the radius is large, and forms the chief part of the wrist.

Carpus, or wrist. — The wrist joint is composed of eight small bones (ossa carpi) united by ligaments; they are arranged in two rows, and are closely welded together, yet by the arrangement of their ligaments allow of a certain amount of motion. They afford origin by their palmar surface to most of the short muscles of the thumb and little finger, and are named as follows: —

1st row.	Scaphoid	1	2d row.	Trapezium	1	8
	Semilunar	1		Trapezoid	1	
	Cuneiform	1		Os Magnum	1	
	Pisiform	1		Unciform	1	

Metacarpus, or body of hand. — Each metacarpus is formed by five bones (ossa metacarpalia). The bones are curved longitudinally, being convex behind, and concave in front. They articulate at their bases with the second row of carpal bones and with each other. The heads of the bones articulate with the bases of the first row of the phalanges.

Phalanges, or digits. — They are the bones of the fingers, and are fourteen in number in each hand, three for each finger and two for the thumb. The first row articulates with the metacarpal bones and the second row of phalanges; the second row, with the first and third; and the third, with the second row.

BONES OF THE LOWER EXTREMITIES

Hip bones (ossa coxæ or ossa innominata)	2	62
Femur (thigh bone)	2	
Patella (knee-cap)	2	
Tibia (shin bone) 2, Fibula (calf bone) 2 — leg	4	
Tarsus (ankle, or root of foot)	14	
Metatarsus (sole and instep)	10	
Phalanges (toes)	28	

The bones of the lower extremities correspond to a great extent with those of the upper extremities, and bear a rough resemblance to them, but are heavier and more firmly knit together.

Hip bone, or os coxa. — It is a large, irregularly shaped bone which, with its fellow of the opposite side, forms the sides and

front wall of the pelvic cavity. In young subjects it consists of three separate parts, and although in the adult these have become united, it is usual to describe the bone as divisible into three portions: (1) the ilium (plural *ilia*), (2) the ischium (plural *ischii*), (3) the pubis (plural *pubes*).

The **ilium** is the upper broad and expanded portion which forms the prominence of the hip. The **ischium** is the lower and strongest portion of the bone, while the **pubis** is that portion which helps to form the front of the pelvis. Where these three portions of the bone meet and finally ankylose, is a deep socket, called the *acetabulum*, into which the head of the femur fits. Other points of special interest to note in the hip bones are: —

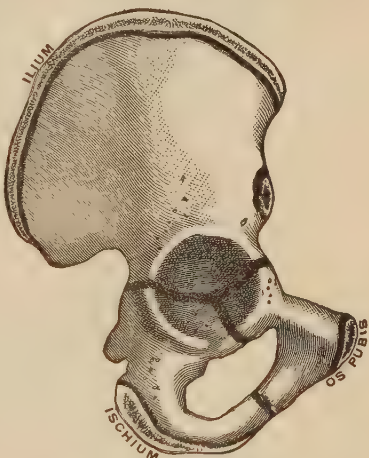


Fig. 58. — Development of the Hip Bone. Showing the union of the three portions in the acetabulum. (Gerrish.)

(1) The spinous process formed by the projection of the *crest* of the ilium in front, which is called the *anterior superior spinous process*, and which is a well-known and convenient landmark in making anatomical and surgical measurements.

(2) The largest foramen in the skeleton, known as the *thyroid foramen*, situated between the ischium and pubis.

(3) The *symphysis pubis*, or pubic articulation, which also serves for a convenient landmark in making measurements.

The pelvis. — The pelvis, so called from its resemblance to a basin, is stronger and more massively constructed than either the cranial or the thoracic cavity. It is composed of four bones, the two hip bones forming the sides and front, the sacrum and coccyx completing it behind. It is divided by a narrowed bony ring into the *large* (false), and *small* (true) pelvis. The narrowed bony ring which is the dividing line is spoken of as the *brim of the pelvis*, the *ilio-pectineal line*, and the *strait*. The large pelvis is all that expanded portion of the pelvis situated above the brim; it forms an incomplete or *false* basin. The small pelvis is all that portion situated below the brim. Its cavity is a little wider in every

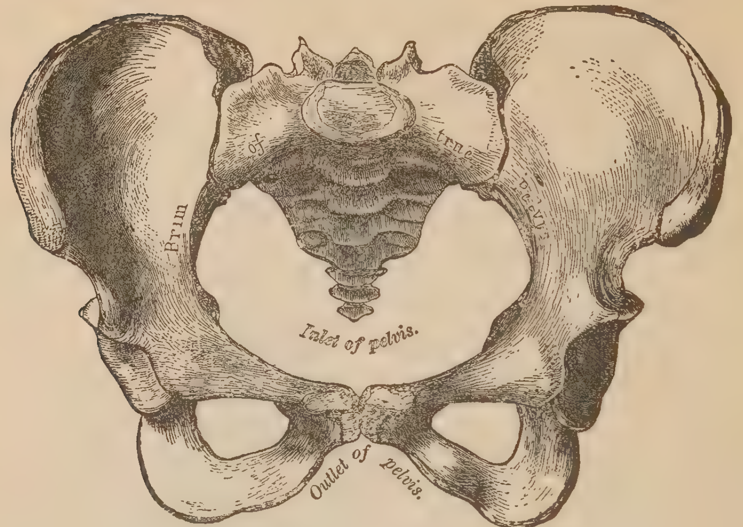


Fig. 59. — Female Pelvis.

direction than the brim itself, while the large pelvis is a great deal wider. The small bony pelvis is a basin with incomplete walls of bone, the bottom of which is composed of the softer tissues, muscles, and ligaments. The opening of the small pelvis, *i.e.*, the

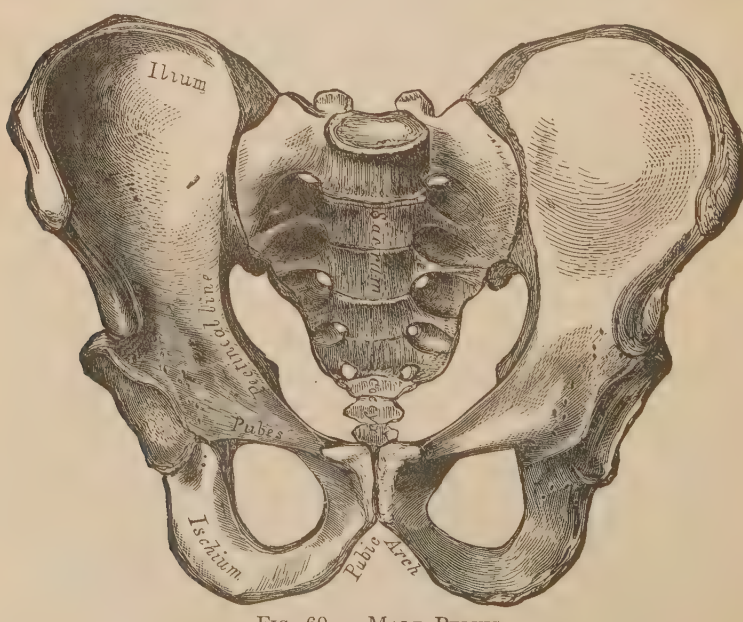


Fig. 60. — Male Pelvis.

space just above the brim, is called the *inlet*, and the opening below is called the *inferior strait*, or *outlet*.

The female pelvis differs from that of the male in those particulars which render it better adapted to pregnancy and parturition. It is more shallow than the male pelvis, but wider in every direction. The inlet and outlet are larger, the bones are lighter and smoother, and the coccyx is more movable. As can be seen by looking at Fig. 59 and Fig. 60 a distinctive anatomical difference is that the sub-pubic angle in a male is less than a right angle, and in the female it is greater than a right angle.

FIG. 61. — THE RIGHT FEMUR, OR THIGH BONE. Anterior view. (Morrow.)

Femur, or thigh bone. — It is the longest, and strongest bone in the skeleton. The upper extremity of the femur, like that of the humerus, consists of a rounded head joined to the shaft by a constricted neck, and of two eminences, called the greater and lesser *trochanters*. The head articulates with the cavity in the hip bone, called the acetabulum. The lower extremity of the femur is larger than the upper, is flattened from before backwards, and divided into two large eminences or *condyles* by an intervening notch. It articulates with the tibia and the patella, or knee-cap. In the erect position it is not vertical, being separated from its fellow by a considerable interval, which corresponds to the entire breadth of the pelvis, but the bone inclines gradually downward and inward, so as to approach its fellow towards its lower part,

in order to bring the knee-joint near the line of gravity of the body. The degree of inclination varies in different persons, and is greater in the female than the male, on account of the greater breadth of the pelvis.

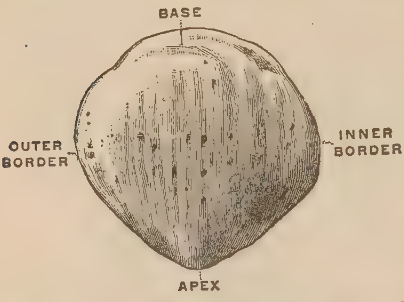


FIG. 62. — THE RIGHT PATELLA. Ventral surface. (Gerrish.)

Patella, or knee-cap. — It is the largest sesamoid bone in the body. It is small, flat, triangular in shape, and placed in front of the knee-joint, which it serves to protect. (See Fig. 30.) It articulates with the two condyles of the femur, and is separated from the skin by a bursa. (See page 143.)

Tibia, or shin bone. — It is situated at the front and inner side of the leg. The upper extremity is large, and expanded into two lateral eminences with concave surfaces, which receive the condyles of the femur. The lower extremity is much smaller than the upper; it is prolonged downward on its inner side into a strong process, the inner, or *medial, malleolus*. It articulates with the fibula and one of the bones of the ankle. (In the male, its direction is vertical and parallel with the bone of the opposite side; but in the female it has a slightly oblique direction outward, to compensate for the oblique direction of the femur inward.)

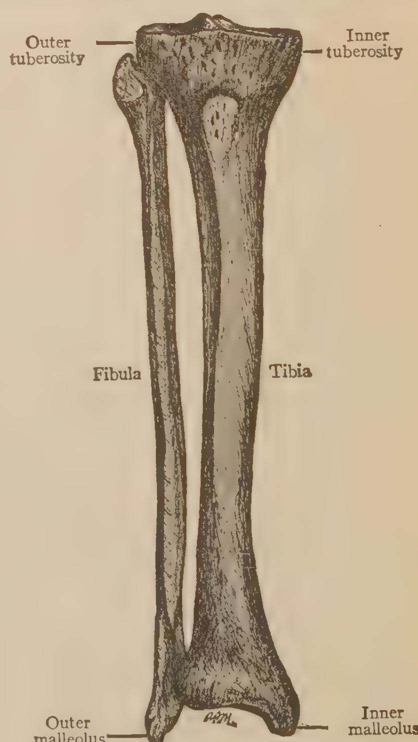


FIG. 63. — THE BONES OF THE RIGHT LEG. (Morrow.)

Fibula, or calf bone. — It is situated at the outer side of the leg. It is the smaller of

the two bones, and, in proportion to its length, the most slender of all the long bones; it is placed nearly parallel with the tibia. The upper extremity consists of an irregular quadrate head by means of which it articulates with the tibia. The lower extremity is prolonged downward into a pointed process, the external, or *lateral, malleolus*, which lies just beneath the skin. It articulates with the tibia and one of the bones of the ankle.

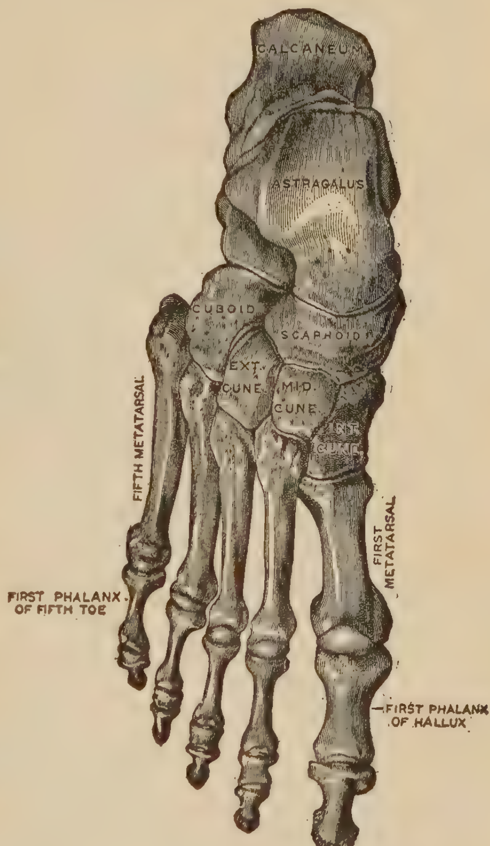


FIG. 64. — THE BONES OF THE RIGHT FOOT. Viewed from above. (Gerrish.)

Tarsus. — The tarsus is composed of seven small bones united by ligaments, but the tarsal bones differ from the carpal in being larger and more irregularly shaped. The largest and strongest of the tarsal bones is called the **calcaneum**, or **heel bone**; it serves to transmit the weight of the body to the ground, and forms a strong lever for the muscles of the calf of the leg. The names are as follows: —

Calcaneum	1	7
Astragalus	1	
Cuboid	1	
Scaphoid	1	
External cuneiform	1	
Middle cuneiform	1	
Internal cuneiform	1	

Metatarsus, or sole and instep of foot. — The metatarsus is formed by five bones which closely resemble the metacarpal bones of the hand. Each bone articulates with the tarsal bones by one extremity, and by the other with the first row of phalanges.

Phalanges, or digits. — Both in number and general arrangement resemble those in the hand, there being two in the great toe and three in each of the other toes.

SUMMARY

Bones
- Function
  1. Organs of support.
  2. Instruments of locomotion.
  3. Framework of hard material.
  4. Afford attachment to soft parts.
  5. Shelter delicate structures.
  6. Shape to whole body.
- Classification
  1. Long.
  2. Short.
  3. Flat.
  4. Irregular.

TABLE OF THE BONES

HEAD

Cranium		**Face**	
Occipital	1	Nasal	2
Parietal	2	Lacrimal	2
Frontal	1	Vomer	1
Temporal	2	Malar	2
Sphenoid	1	Palate	2
Ethmoid	1	Inferior turbinated	2
	8	Maxilla	2
		Mandible	1
			14

Ear	Malleus	2
	Incus	2
	Stapes	2
		6

Hyoid bone in the neck	1

TRUNK

		Child	Adult
Vertebræ	Cervical	7	7
	Thoracic	12	12
	Lumbar	5	5
	Sacral	5	1
	Coccygeal	4=33	1=26
	Ribs		24
	Sternum		1
			51

Upper Extremity

Clavicle		1
Scapula		1
Humerus		1
Ulna		1
Radius		1
Carpus	Scaphoid	1
	Semilunar	1
	Cuneiform	1
	Pisiform	1
	Trapezium	1
	Trapezoid	1
	Os magnum	1
	Unciform	1
Metacarpus		5
Phalanges		14
		32

$32 \times 2 = 64$

Lower Extremity

Hip bone (os coxa)		1
Femur		1
Patella		1
Tibia		1
Fibula		1
Tarsus	Calcaneum	1
	Astragalus	1
	Cuboid	1
	Scaphoid	1
	External cuneiform	1
	Middle cuneiform	1
	Internal cuneiform	1
Metatarsus		5
Phalanges		14
		31

$31 \times 2 = 62$

CHAPTER VI

JOINTS OR ARTICULATIONS

Joints or articulations. — The various bones of which the skeleton consists are connected at different parts of their surfaces, and such connections are called joints or articulations.

CLASSIFICATION

Joints are classified according to the amount of movement of which they are capable.

1. Immovable joints or synarthroses.
2. Slightly movable joints, or amphiarthroses.
3. Freely movable joints, or diarthroses.

In all instances some softer substance is placed between the bones, uniting them or clothing the opposed surfaces; but the manner in which the several pieces of the skeleton are thus connected varies to a great degree.

IMMOVABLE JOINTS, OR SYNARTHROSES

The bones are connected by fibrous tissue or cartilage.

The bones of the cranium and the facial bones (with the exception of the lower jaw) have their adjacent surfaces applied in close contact, with only a thin layer of fibrous tissue placed between their margins.

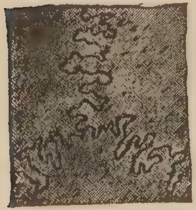


Fig. 65. — A Toothed, or Dentated, Suture.

In most of the cranial bones this union occurs by means of toothed edges which dovetail into one another and form jagged lines of union known as **sutures**.

The three most important sutures are: —

(1) **Coronal.** — The line of union between the frontal and parietal bones.

(2) **Lambdoidal.** — The line of union between the parietal and occipital bones.

(3) **Sagittal suture.** — This begins at the base of the nose,

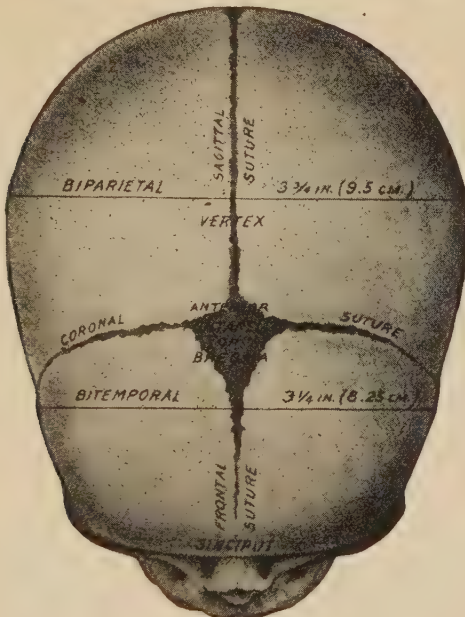


FIG. 66. — DIAMETERS AND LANDMARKS OF THE FŒTAL SKULL. Upper surface. (Edgar.)

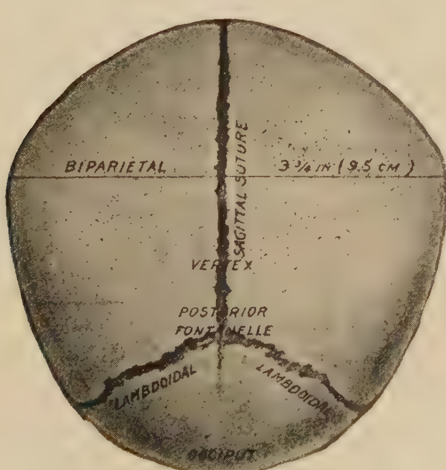


FIG. 67. — DIAMETERS AND LANDMARKS OF THE FŒTAL SKULL. Posterior surface. (Edgar.)

extends along the middle line on the top of the crown, separates the frontal bone into two parts,[1] the parietal bones from each other, and ends at the posterior fontanelle.

Synchondrosis is usually a temporary form of joint. The cartilage between the bones ossifies before adult life. Example: the union of the sphenoid and occipital bones.

SLIGHTLY MOVABLE JOINTS, OR AMPHIARTHROSES

The above terms apply to joints that permit of slight movement and include two varieties: (1) symphysis and (2) syndesmosis.

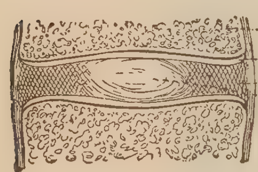


FIG. 68. — A SLIGHTLY MOVABLE JOINT.

Symphysis. — In this form of articulation the bony surfaces are joined together by broad, flattened disks of fibro-cartilage, as in the articulations between the bodies of the vertebræ. These intervertebral disks being compressible and extensile, the spine can be moved to a limited extent in every direction. In the pelvis the articulations between the two pubic bones (symphysis pubis),[2] and between the sacrum and ilia (sacro-iliac articulation), are slightly movable. The pubic bones are united by a disk of fibro-cartilage and by ligaments. In the sacro-iliac articulation the sacrum is united more closely to the ilia, the articular surfaces being covered by cartilage and held together by ligaments.

The fibro-cartilage between these joints (symphysis pubis and sacro-iliac) becomes thickened and softened during pregnancy and allows of a certain limited motion which is essential to a normal parturition.

Syndesmosis. — An articulation by means of an interosseous ligament, as in the lower tibio-fibular articulation, is called syndesmosis.

FREELY MOVABLE JOINTS, OR DIARTHROSES

This division includes the complete joints, which are the only joints in which the three following conditions are found: —

(1) The bones are united by fibrous ligaments, forming more

[1] That portion of the sagittal suture which separates the frontal bone into two parts is often called the *frontal suture*. (See Fig. 66.)

[2] See Fig. 59.

or less perfect capsules. The ligaments are not always so tight as to maintain the bones in close contact in all positions of the joint, but are rather tightened in some positions and relaxed in others, so that in many cases they are to be looked on chiefly as controllers of movements, and not as serving solely to hold the bones together. The bones are held together in these joints partly by atmospheric pressure and largely by the surrounding muscles.

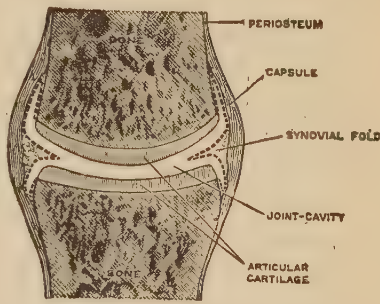


FIG. 69. — A COMPLETE JOINT. The synovial membrane is represented by dotted lines.

(2) A secreting membrane (synovial)[1] lines the capsule and is so arranged that it dips in between the edges of the opposing articular cartilages. (See Fig. 69.)

(3) Each articular end of the bone is covered by hyaline cartilage which provides surfaces of remarkable smoothness, and these surfaces are lubricated by the synovial fluid secreted from the delicate synovial membrane which lines the cavity of the joint.

The varieties of joints in this class have been determined by the kind of motion permitted in each. They are as follows: —

(1) **Gliding joint.** — The articular surfaces are nearly flat, and admit of only a limited amount of gliding movement, as in the joints between the articular processes of the vertebræ.

(2) **Hinge joint.** — The articular surfaces are of such shape as to permit of movement to and fro in one plane only, like a door on its hinges. These movements are called flexion and extension, and may be seen in the articulation of the arm with the forearm, in the ankle joint, and in the articulations of the phalanges.

(3) **Ball-and-socket joint.** — In this form of joint a more or less rounded head is received into a cup-like cavity, as the head of the femur into the acetabulum, and the head of the humerus into the glenoid cavity of the scapula. Movement can take place freely in any direction, but the shallower the cup, the greater the extent of motion. The shoulder joint is the most freely movable joint in the body.

[1] See page 142.

(4) **Pivot joint.** — In this form, one bone rotates around another which remains stationary, as in the articulation of the atlas with the axis (epistropheus), and in the articulation of the ulna and radius. In the articulation of the ulna and radius, the ulna remains stationary, and the radius rotates freely around its upper end. The hand is attached to the lower end of the radius, and the radius, in rotating, carries the hand with it; thus, the palm of the hand is alternately turned forward and backward. When the palm is turned forward, or upward, the atitude is called supination; when backward, or downward, pronation.

(5) **Condyloid joint.** — When an oval-shaped head, or condyle, of a bone is received into an elliptical cavity, it is said to form a condyloid joint. An example of this kind of joint is found in the metacarpo-phalangeal articulations. The rounded heads of the metacarpal bones are received in the elliptical-shaped bases of the phalanges.

(6) **Saddle joint.** — In this joint the articular surface of each bone is concave in one direction, and convex in another, at right angles to the former. A man seated in a saddle is "articulated" with the saddle by such a joint. For the saddle is concave from before backward, and convex from side to side, while the man presents to it the concavity of his legs astride, from side to side, and the convexity of his seat, from before backward. The metacarpal bone of the thumb is articulated with the trapezius of the carpus by a saddle joint. Both the condyloid and saddle joints admit of motion in every direction except that of axial rotation.

Movement. — Bones thus connected are capable of the following different kinds of movement.

1. *Flexion.* — A limb is flexed, when it is bent.
2. *Extension.* — A limb is extended, when it is straightened out.
3. *Abduction.* — This term means drawn away from the middle line of the body.
4. *Adduction.* — This term means brought to, or nearer the middle line of the body.

Both abduction and adduction have a different meaning when used with reference to the fingers and toes. In the hand the imaginary line is supposed to be drawn through the middle finger; and in the foot through the second toe.

5. *Rotation.* — Means made to turn on its own axis.

6. *Circumduction.* — Means made to describe a conical space by rotation around an imaginary axis.

No part of the body is capable of perfect rotation, as a wheel, for the simple reason that such motion would necessarily tear asunder all the vessels, nerves, muscles, etc., which unite it with other parts.

Sprain. — A wrenching or twisting of a joint accompanied by a stretching or tearing of the ligaments or tendons is called a sprain.

Dislocation. — If in addition to a sprain, the bone is displaced, the injury is called a dislocation.

SUMMARY

Joints or Articulations — connections existing between bones.

- **Immovable Joint or Synarthrosis,** — Bones are connected by fibrous tissue or cartilage.
  1. *Sutura.* — Articulations by processes and indentations interlocked together. A thin layer of fibrous tissue is interposed between the bones. Sutures may be dentated, dove-tailed; serrated, saw-like; squamous, scale-like; harmonic, smooth; and grooved, for the reception of thin plates of bone.
  2. *Synchondrosis.* — Temporary joint. Cartilage between bones ossifies in adult life.
- **Slightly Movable Joint or Amphiarthrosis,** — Bones are connected by discs of cartilage or interosseous ligaments.
  1. *Symphysis.* — The bones are united by a plate or disc of fibro-cartilage of considerable thickness.
  2. *Syndesmosis.* — The bony surfaces are united by an interosseous ligament, as in the lower tibio-fibular articulation.
- **Movable Joint or Diarthrosis,**
  - 1. Fibrous ligament forming a capsule.
  - 2. Synovial membrane lining fibrous capsule.
  - 3. Hyaline cartilage covering articular ends of bones.

  1. *Arthrodia.* — Gliding joint; articulates by plane surfaces which glide upon each other.
  2. *Ginglymus.* — Hinge or angular joint; moves backward and forward in one plane.
  3. *Enarthrosis.* — Ball-and-socket joint; articulates by a globular head in a cup-like cavity.
  4. *Trochoides.* — Pivot joint; articulates by a pivot process turning within a ring, or by a ring turning around a pivot.
  5. *Condylarthrosis.* — Condyloid joint; ovoid head received into elliptical cavity.
  6. *Reciprocal Reception.* — Saddle joint; articular surfaces are concavo-convex.
- **Movement**
  - Flexion.
  - Extension.
  - Abduction.
  - Adduction.
  - Rotation.
  - Circumduction.

CHAPTER VII

MUSCULAR TISSUE: CLASSIFICATION; FUNCTIONALLY IMPORTANT SKELETAL MUSCLES

MUSCULAR TISSUE

THIS is the tissue by means of which the movements of the body are produced. It constitutes the fleshy parts, enters into the structure of many of the internal organs, and forms from 40 to 50 per cent of the body weight.

Muscular tissue, like every other tissue, is composed of cells and intercellular substance, with this special difference, that the cells become elongated. The intercellular substance consists of a small amount of cement, which helps to hold the cells together. The cells are really bound into bundles by a framework of reticular tissue.

CLASSIFICATION

Muscle cells are of three distinct kinds, and we therefore distinguish three varieties of muscular tissue: —

1. Striated or cross-striped;
2. Non-striated or plain;
3. Cardiac.

Striated or cross-striped muscular tissue. — This tissue is called striated because it is distinctly marked by striæ, or parallel cross stripes. It is also called *skeletal* because it forms the muscles which are attached to the skeleton, and *voluntary* because it is nearly always under the control of the will. It is composed of long slender cells, measuring on an average $\frac{1}{500}$ inch (0.05 mm.) in diameter, but having a length of an inch or more.

Each cell consists of three distinct elements: —

(1) *Contractile substance*, forming the centre and making up most of the bulk of the cell.

(2) *Nuclei,* which lie scattered upon the surface of the contractile substance;

(3) The *sarcolemma,* a thin, structureless tube which tightly encloses the contractile substance and the nuclei.

As each cell contains a number of nuclei, we may regard it as a multinuclear cell of elongated form. The muscle cells lie closely packed, their ends lapping over on to adjacent cells and forming bundles. Delicate reticular tissue penetrates between the cells, surrounds the small bundles and groups them into larger bundles. Reticular tissue also surrounds the larger bundles and forms a covering for the whole muscle. Thus it will be seen that reticular tissue forms a supporting framework for muscular tissue.

Fig. 70.—Diagram of Muscle Cell with Sarcolemma Attached.

Skeletal Muscles. — The muscles are separate organs, each muscle having its own sheath of connective tissue, called epimysium. They vary in size from a fraction of an inch to nearly twenty-four inches (60 cm.) and are very diverse in form. In the trunk the muscles are broad, flattened, and expanded, forming the walls of the cavities which they enclose. In the limbs they are of considerable length, forming more or less elongated straps. A typical muscle is described as consisting of a body and two extremities. The body is the red contracting part, and the extremities are the ends where they are attached.

Attachment of the muscles to the skeleton. — Muscles are attached to the bones, cartilages, ligaments, and skin in various ways, the most common mode of attachment being by means of *tendons.* The muscle fibres converge as they approach their tendinous extremities, and gradually blend with the fibres of the tendons, the tendons in their turn inserting their fibres into the bones. Where one muscle connects with another, each muscle ends in expanded form in a flat, fibrous membrane called an *aponeurosis.* Again, in some cases, the muscles are connected with the bones, cartilages, and skin, without the intervention of tendons or aponeuroses.

Fasciæ. — As previously stated (page 47), most of the muscles are closely covered by sheets of fibrous tissue called fasciæ. These

fasciæ not only envelop and bind down the muscles, but also separate them into groups. Such groups are named according to the parts of the body where they are found, viz.: cervical fascia, thoracic fascia, abdominal fascia, pelvic fascia, etc. Individual fasciæ are frequently given the names of the muscles which they envelop and bind down, viz.: temporal fascia, pectoral fascia, deltoid fascia, etc. It is important for the student to realize the continuity of the fibrous membranes. Tendons, ligaments, and fasciæ blend with periosteum; tendons and fasciæ serve as ligaments; tendons lose themselves in fasciæ; and tendons of some muscles serve as fasciæ for others.

Annular ligaments. — In the vicinity of the wrist and ankle, parts of the deep fascia become blended into tight transverse bands, which serve to hold the tendons close to the bones. These bands are called annular ligaments. (See Fig. 89.)

Origin and insertion. — It is customary to speak of the attachments of the opposite ends of muscles under the names of origin and insertion, the first term *origin* being usually applied to the more fixed attachment; the second term *insertion* being applied to the more movable attachment. The origin is, however, absolutely fixed in only a very small number of muscles, such as those of the face, which are attached by one end to the bone, and by the other to the movable skin. In the greater number, the muscle can act from either end.

Non-striated or plain muscular tissue. — This tissue is called plain or non-striated because it does not exhibit parallel transverse *striæ* or stripes. It is also called *visceral* because it constitutes a large portion of the substance of many of the viscera, and *involuntary* because it is usually withdrawn from the control of the will. It is composed of elongated cells containing a single elongated nucleus. These cells are always much shorter than the cells of striated tissue. They lie side by side or lap over one another at the ends and are joined together by a small amount of cement substance.

FIG. 71. — ELONGATED CELLS OF PLAIN MUSCULAR TISSUE. (Highly magnified.)

The cells are variously grouped in different parts of the body; sometimes crowded together in solid bundles which are arranged in layers and surrounded by reticular tissue, as in the intestines; sometimes arranged in narrow, interlacing bundles, as in the bladder; sometimes wound in layers around the blood-vessels; and again running in various directions and associated with bands of reticular tissue, they form large, compact masses, as in the uterus.

Cardiac muscular tissue. — This variety of muscular tissue is found only in the heart substance. It is involuntary, but is striated, though not as distinctly as skeletal muscle. It is made up of cells which are short, contain just one nucleus, and no sarcolemma. The cells are grouped in bundles which are nearly square, and fine fibrils from each cell help to hold the bundles together. The bundles are mainly held by reticular tissue, which forms a supporting framework in the heart, just as it does in skeletal and visceral muscle.

Characteristics. — Muscular tissue is highly specialized and exhibits irritability, contractility, extensibility, elasticity, and tonicity.

Irritability has been defined as the response of a tissue to a stimulus. All cells possess this property; nerve tissue, ciliated epithelial cells, and muscular tissue in a marked degree. The response of any tissue to stimulation is to perform its special function, and in the case of muscular tissue this response takes the form of contraction.

Contractility is the power which enables muscles to change their shape so as to become shorter and thicker. It is possessed to some degree by all living protoplasm, but is highly developed in muscular tissue, the sum of the contractions of such tissue resulting in motion. Muscular contractility takes place along definite lines corresponding to the long axes of the cells. The shortening is the essential part and the thickening incidental. The function of the reticular framework is passive and may be likened to that of a harness, through which all the numerous contractile cells are enabled to unite their efforts.

Extensibility of a living muscle means that it can be stretched or extended, and *elasticity* means that it readily returns to its original form. Normally, the skeletal muscles are in a condition of

slight tension, being stretched from bone to bone. This condition is of importance in two ways: (1) smoothness of movement is dependent upon it; (2) a stretched muscle will contract more quickly than one that is relaxed. To understand the first statement it is important to remember that skeletal muscles are usually arranged in antagonistic groups, one of which opposes the other. Thus the muscles located on the anterior surface of the arm and forearm are called flexors, and those located on the posterior surface are called extensors. The action of the flexors is to bend the arm, the action of the extensors is to extend or straighten the arm. When stimulated, either group of muscles must overcome the resistance of the opposing group. Therefore contraction takes place more slowly and evenly, and smoothness of movement is the result.

Tonicity is the constant and insensible tendency to contract which exists under normal conditions. It is really a mild, sustained contraction, and though it may vary in degree, it is rarely absent altogether. Tone in the skeletal muscles gives them a certain firmness and maintains a slight steady pull upon their attachments. It is not likely to result in movement on account of the action of an antagonistic muscle. In fractures the over-riding of the broken ends of a bone is often due to the contraction of the muscle that is the result of its tonicity.

Function. — The function of muscles is to contract, and the functional value of muscles depends upon this property. The contraction of a number of muscles is expressed in motion. Accordingly, contraction is the means by which all the various muscular activities of the body are made possible.

Stimuli. — This term is used to describe influences which stimulate muscle cells. They may be chemical, mechanical, thermal, electrical, or nervous. From the standpoint of physiology the nervous impulse is the most important.

Varieties of muscular movements. — According to their causation we divide muscular movements into two classes; voluntary, and involuntary or automatic. (1) The movements of the skeletal muscles (voluntary) are all due to influences brought to bear through the central nervous system. Every step that we take is the result of a distinct act on the part of a nerve centre in the brain. (2) On the contrary the contractions of the heart are due

to an inherent rhythmic tendency of the muscle itself. We express this fact by saying that cardiac muscle is automatic, and the same is true in a general way of all visceral muscles (involuntary). We must become familar with the idea that stimuli from the nervous system not only excite muscular activity (as in the skeletal muscles) but also increase or decrease the degree of activity. The influence of the nervous system on the activity of automatic muscular tissue is the latter, *i.e.*, to increase or decrease it.

Nerves. — Muscular tissue is well supplied with nerves. Certain nerves convey impulses from the central nervous system to the muscles and control their contraction. These are called motor nerves. Certain other nerves have sensory end organs in the muscles. These convey to the central nervous system the state of contraction of the muscle and hence are called sensory nerves. By means of these sets of nerves coördinated activities of groups of muscles are brought about.[1]

Conditions of contraction. — Skeletal muscle is essentially a quick-acting tissue. It contracts quickly and relaxes promptly. In sharp contrast to this, the contractions of visceral muscle develop slowly, are maintained for some time, and fade out slowly. The contraction of any one muscle is the result of a series of stimuli discharged rhythmically by the nerve cells innervating it. If one of these contractions is analyzed it will be found that there is a brief period after the muscle is stimulated before it contracts. This is called the latent period and is followed by a period of contraction, which in turn is followed by a period of relaxation. If we give 0.10 of a second as the reaction time of a *given* muscle, 0.01 might represent the latent period, 0.04 the contraction period, and 0.05 the relaxation period. It is easy to understand how this might vary, depending upon (1) the strength of the stimuli; (2) the duration of the stimulus; (3) the quality of the muscle substance; and (4) the temperature. Muscles do their best work at a certain optimum temperature which differs somewhat for different muscles. If the temperature is raised beyond a certain upper limit the muscle loses its irritability and becomes functionally depressed, entering finally the state of heat rigor, *i.e.*, a condition of permanent shortening.

Tetanus. — When a muscle receives a series of repeated stimuli

[1] See "Muscle sense," Chapter XX.

so rapidly that there are no periods of relaxation, it remains in a condition of contraction as long as the stimuli are sent in, or until it loses its irritability from fatigue. A contraction of this kind is described as a compound contraction or *tetanus*.

Blood supply and source of energy. — All varieties of muscular tissue are well supplied with blood-vessels which are supported and carried by the connective tissue. They do not penetrate into the cells, but each cell is bathed in lymph which exudes from the blood-vessels. One of the substances brought by the blood to the muscles is glycogen.[1] This is stored in the cells and represents potential energy, which stimuli may transform into mechanical energy. The transformation of energy which accompanies muscular activity is associated with the oxidation of glycogen and perhaps fat, and the formation of waste compounds, *i.e.*, carbon dioxide, water, and lactic acid. These waste compounds must be eliminated, and, except in cases of prolonged contractions, the system is able to get rid of them readily.

Fatigue. — Prolonged contractions result in *fatigue*, and this means two things: (1) an accumulation of waste substances, which act as poisons, (2) a loss of nutrient material. A period of rest furnishes opportunity for the blood to carry these fatigue poisons to the excretory organs; and nutritive materials from the digestive organs to the muscles. In cases of extreme fatigue resulting from prolonged overwork the fatigue poisons circulate in the blood and lessen the irritability of muscular tissue so that it fails to respond to stimuli. It has been demonstrated that the injection of the blood of a fatigued animal into a rested one will promptly bring on signs of fatigue.

Lohere.

FUNCTIONALLY IMPORTANT SKELETAL MUSCLES

The skeletal muscles are usually called by their Latin names, and it is helpful to understand the meaning of these names, as they are often descriptive of some distinctive characteristic, such as their form, size, attachment, location, function, etc.

The majority occur in pairs. Only a few are single, and they are located about the median line. Muscles may be classified in several ways. The most helpful way is to classify them according

[1] See Chapter XVI.

to their location and function. It is most important for nurses to know in a general way the location, and in a definite way the function of the principal muscles of the body.

CHIEF MUSCLES OF HEAD, FACE, TONGUE, AND NECK

Muscles of the Head	Occipito-frontalis	
Muscles of the Face	Orbital Muscles	Four recti.
		Two oblique.
		Levator palpebræ superioris.
	Muscles of Mastication	Masseter.
		Temporal.
		Internal pterygoid.
		External pterygoid.
	Muscles of Expression	Orbicularis oris.
		Buccinator.
Muscles of the Tongue	Genioglossus.	
	Styloglossus.	
Muscles of the Neck	Platysma.	
	Sterno-cleido-mastoid.	

Muscles of the head. — The chief muscle of the head is the occipito-frontalis, which may be considered as two muscles united together by a thin aponeurosis extending over and covering the whole of the upper part of the cranium. The occipital takes its origin from the occipital bone and is inserted into the aponeurosis. The frontal takes its origin from the tissues in the region of the eyebrows, and is also inserted into the aponeurosis.

Action. — The frontal portion of this muscle is the more powerful; by its contraction the eyebrows are elevated, and the skin of the forehead thrown into transverse wrinkles.

Muscles of the face. — There are about thirty facial muscles; they are chiefly small, and only a few are considered. We group them as: (1) Orbital muscles, (2) Muscles of mastication, and (3) Muscles of expression.

Orbital muscles. — The orbit contains seven muscles; six of them are attached to the eyeball, and the seventh is attached to the upper lid. The six muscles attached to the eyeball are arranged in three opposing pairs.

The superior and inferior recti. — These two muscles have their origin at the apex of the orbital cavity and pass straight forward

to their insertion into the eyeball, the superior rectus in the middle line above, and the inferior rectus opposite it below.

Action. — Contraction of the superior rectus rolls the eye upward; contraction of the inferior rolls the eye downward.

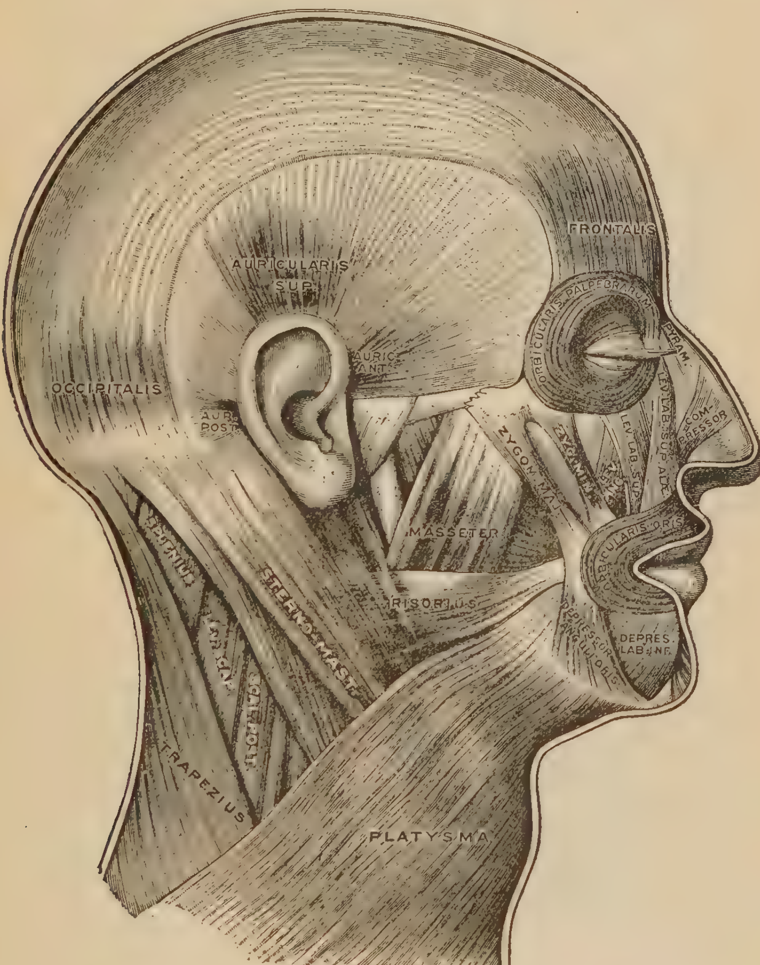


FIG. 72. — SUPERFICIAL MUSCLES OF HEAD AND NECK. (Gerrish.)

The internal and external recti. — These two muscles have their origin at the apex of the orbital cavity, and pass forward to their insertion into the eyeball; the internal on the inner side, the external on the outer side.

Action. — Contraction of the internal rectus draws the eye inward towards the nose. Contraction of the external rectus draws the eye outward.

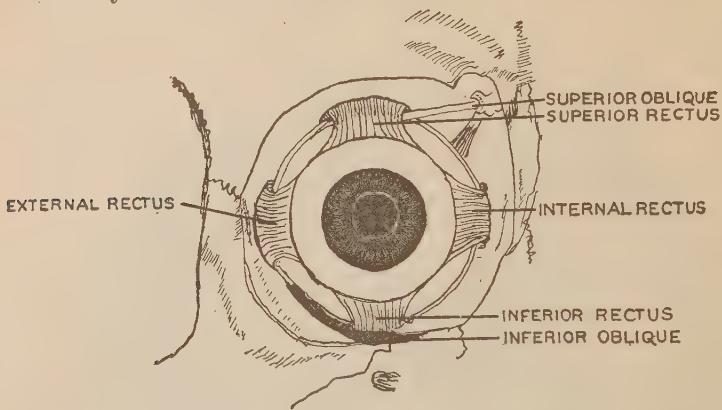


Fig. 73. — Muscles of the Right Eyeball within the Orbit. (Seen from the front.)

Superior oblique. — The superior oblique muscle arises from the apex of the orbit (the same as the four recti), courses forward to the upper and inner angle of the orbit, where it passes through a

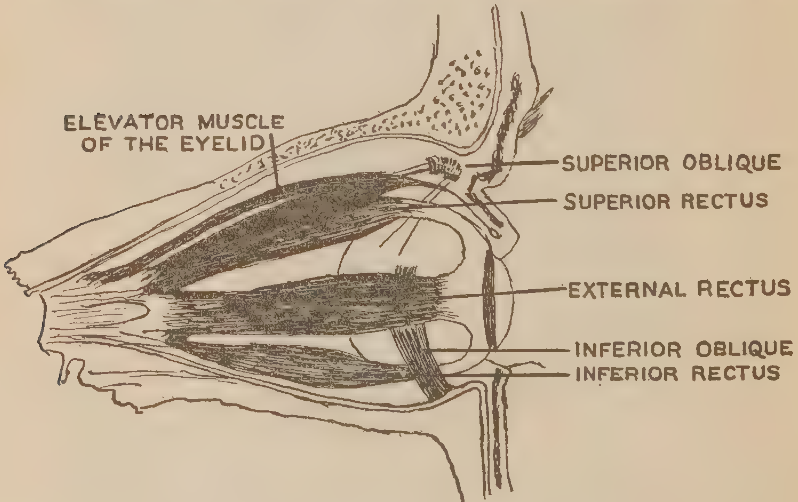


Fig. 74. — Muscles of the Eyeball. (Seen from side.)

loop of cartilage. Then it bends at an actue angle, passes around the upper part of the eyeball, and is inserted between the superior and external recti.

Inferior oblique. — The inferior oblique arises from the orbital plate of the maxilla, and courses around the under portion of the eyeball to its attachment near the external rectus.

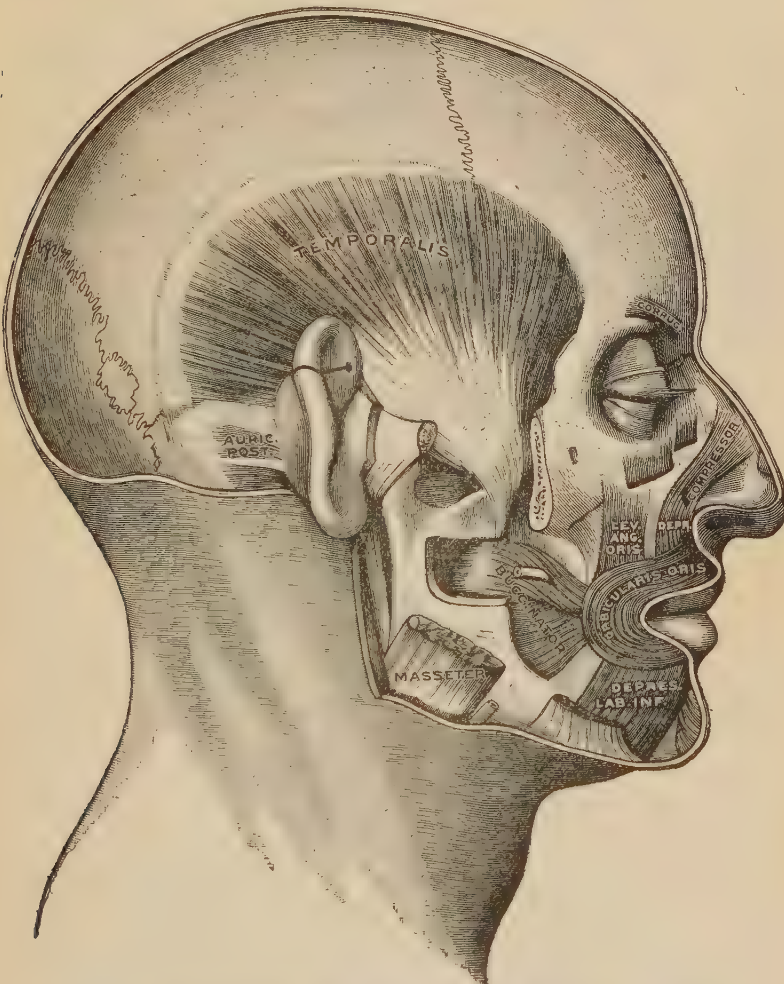


FIG. 75. — TEMPORAL AND DEEP MUSCLES ABOUT THE MOUTH. (Gerrish.)

Action. — The action of the two oblique muscles is somewhat complicated, but their general tendency is to roll the eyeball on its axis.

In most cases the movements of the eye are somewhat complex and more than one muscle is involved.

Levator palpebræ superioris (lifter of the upper lid).—It arises from the sphenoid bone, passes forward, and is inserted into the tarsal cartilage of the upper lid.

Action.—It elevates the upper lid and opens the eye.

Muscles of mastication.—They are: (1) the masseter (chewing muscle), (2) the temporal (temple muscle), (3) the internal

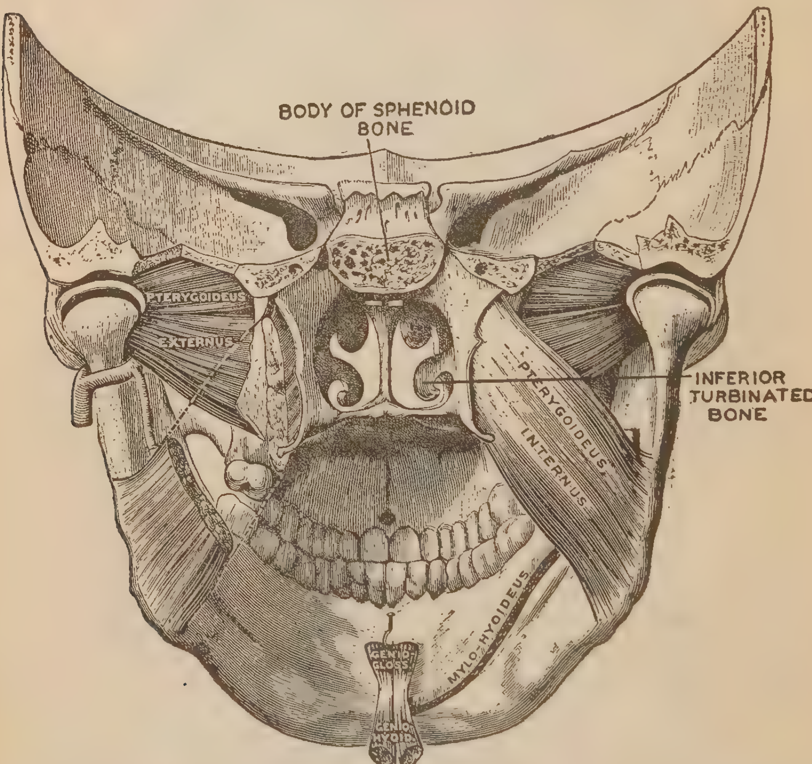


FIG. 76.—PTERYGOID MUSCLES. Viewed from behind, the back portion of the skull having been removed. (Gerrish.)

pterygoid, and (4) the external pterygoid. These muscles can be located on the illustrations. They have their origin in one or more of the immovable bones of the skull, and are inserted into the movable lower jaw.

Action.—(1) The masseter raises the mandible. (2) The temporal raises the mandible, and the most posterior fibres serve to retract the jaw. (3) The chief action of the internal pterygoid is to raise the jaw; it also assists the external pterygoid in pro-

truding the jaw and in producing lateral movements. (4) When both external pterygoid muscles act together they draw the jaw forward. The internal and external pterygoid of one side produce lateral movements of the jaw.

These muscles generally act in concert, bringing the lower teeth forcibly into contact with the upper; they also move the lower jaw forward upon the upper, and in every direction necessary to the process of grinding the food.

Muscles of expression. — These muscles are sometimes called mind muscles from the indications that they afford of the mental state of the individual. They are closely connected with the under surface of the skin or with each other, and therefore their slightest contraction is shown on the face. They include the muscles of the forehead, eyelids, nose, and all those related to the orifice of the mouth. We shall only consider two important muscles related to the orifice of the mouth.

Orbicularis oris.—The ring muscle surrounds the opening of the mouth, extending from the nose above to the chin below. It forms a great part of the bulk of the lips, and constitutes a sphincter to the mouth. It is attached above to the partition between the nostrils and the upper jaw bones, and below to the mandible.

Action. — It causes compression and closure of the lips in various ways, *e.g.*, tightening the lips over the teeth, contracting them, or causing pouting or protrusion of one or the other.

Buccinator (trumpeter's muscle). — This muscle arises from the alveolar processes of the maxilla and mandible. Its different parts converge to the angle of the mouth, and are inserted into the orbicularis oris.

Action. — It retracts the angles of the mouth, flattens the cheeks, and brings them in contact with the teeth.

Chief muscles of the tongue. — The chief muscles connecting the tongue and hyoid bone to the lower jaw are the genioglossus and the styloglossus.

Genioglossus. — The genioglossus has its origin in the front part of the mandible, and is inserted in the whole length of the tongue in and at the side of the midline.

Action. — It thrusts the tongue forward, retracts it, and also depresses it.

Styloglossus. — The styloglossus has its origin in the styloid process of the temporal bone, and is inserted in the whole length of the side and under part of the tongue.

Action. — It retracts the tongue and depresses it.

These muscles are interesting to us from the fact that during general anæsthesia they, together with the other muscles, become

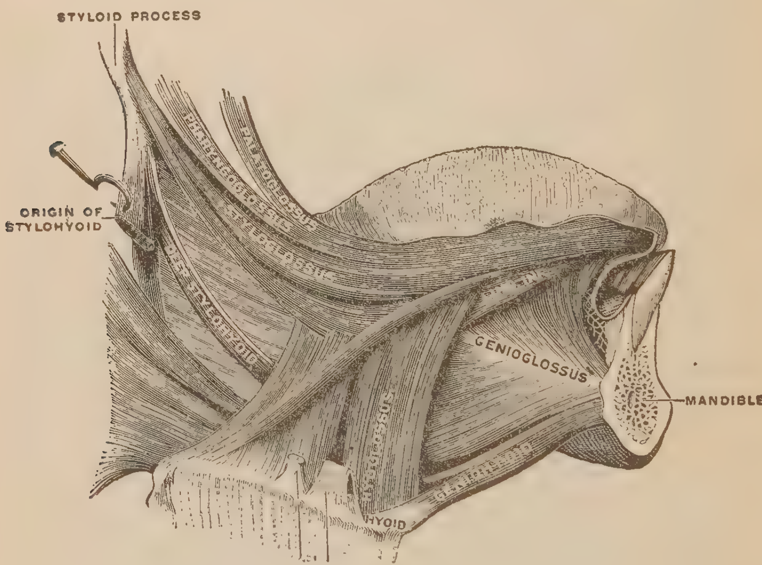


Fig. 77. — Muscles of the Tongue. Viewed from the right side. (Gerrish.)

relaxed, and it is necessary to press the angle of the lower jaw upward and forward in order to prevent the tongue from falling backward and obstructing the larynx.

Muscles of the neck. — The two superficial muscles of the neck are: (1) platysma, (2) sterno-cleido-mastoid.

Platysma (broad sheet muscle). — It arises from the skin and areolar tissue covering the pectoral, deltoid, and trapezius muscles, and is inserted in the mandible and muscles about the angle of the mouth.

Action. — It depresses the mandible, and laterally flexes the head. It also wrinkles the skin of the side of the neck.

Sterno-cleido-mastoid. — The most prominent muscle of the neck is the sterno-cleido-mastoid. It is named from its origin and insertion, arising from part of the sternum and clavicle, and

being inserted into the mastoid portion of the temporal bone. This muscle is easily recognized in thin persons by its forming a cord-like prominence obliquely situated along each side of the neck.

Action. — When one muscle acts alone, it flexes the head laterally, and rotates it to the opposite side. Both muscles acting together (1) flex the head in a forward direction, and (2) serve as extraordinary muscles of inspiration, by raising the sternum and clavicles. If one of these muscles be either abnormally contracted or paralyzed, we get the deformity called *Torticollis* or wry neck.

CHIEF MUSCLES OF THE TRUNK

They may be arranged in four groups: —

1. Muscles of the Back	Trapezius. Latissimus dorsi. Erector spinæ (Sacrospinalis).
2. Muscles of the Chest	Pectoralis major. Pectoralis minor. Serratus magnus (Serratus anterior).
3. Muscles of the Thorax	External intercostals. Internal intercostals. Levatores costarum.
4. Muscles of the Abdomen	External oblique. Internal oblique. Rectus abdominis. Transversalis. Quadratus Lumborum.

Muscles of the back. — The muscles of the back are disposed in five layers, one beneath another. Our list includes only the two large muscles, trapezius and latissimus dorsi, which form the superficial layer, and the erector spinæ, which forms the fourth layer.

Trapezius. — The trapezius, so called because right and left together make a large diamond-shaped sheet, arises from the middle of the occipital bone, from all the cervical and all the thoracic vertebræ. The connection with the cervical vertebræ is through the medium of the *ligamentum nuchæ*, which is a form of ligament that stretches from the protuberance of the occiput to the spinous processes of the seven cervical vertebræ. (See Fig.

78.) From this extended line of origin the fibres converge to their insertion in the clavicle, the acromion process, and the spine of the scapula. It is a very large muscle, and covers the other muscles of the upper part of the back and neck, also the upper portion of the latissimus dorsi.

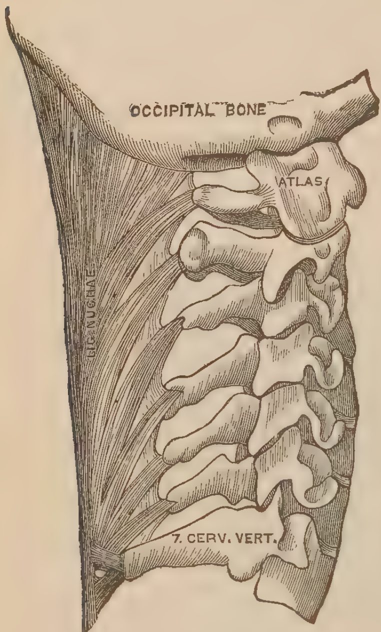


FIG. 78. — THE LIGAMENTUM NUCHÆ, Seen from the right side. (Gerrish.)

Action. — The action of the trapezius must be considered in three parts. The upper fibres raise the shoulder, the middle fibres adduct the scapula, and the lower fibres rotate the lower angle of the scapula toward the median line.

Latissimus dorsi. — The latissimus dorsi arises from the last six thoracic vertebræ, and through the medium of the lumbar aponeurosis, from the lumbar and sacral part of the spine and from the crest of the ilium. It covers the lower part of the back. The fibres pass upward and converge into a thick, narrow band, which winds around and finally terminates in a flat tendon, which is inserted into the front of the humerus just below its head.

Action. — It draws the arm to the side, draws it downward and backward, and rotates the humerus inward.

Erector spinæ. — The fourth layer of the muscles of the back is formed by the erector spinæ (sacrospinalis) which constitutes the greater part of the long rounded mass located on either side of the series of vertebral spinous processes. It extends from the lower and back part of the sacrum, the back portion of the ilia and the spines of the lumbar vertebræ to the cervical vertebræ and the mastoid processes of the temporal bones. It is a compound muscle beginning below in a single mass which soon divides into three portions, two of which, the outer and middle, further subdivide into three portions as follows: —

Erector Spinæ (Sacrospinalis)	Outer Division: —	Ilio-costalis Accessorius ad ilio-costalem Cervicalis ascendens.
	Middle Division: —	Longissimus dorsi Transversalis cervicis Trachelo-mastoideus.
	Inner Division: —	Spinalis dorsi.

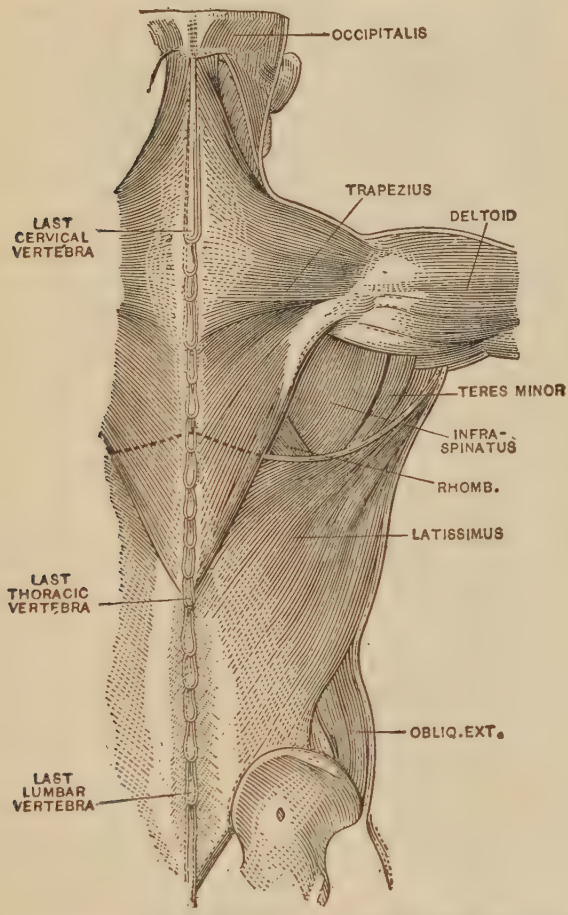


FIG. 79. — MUSCLES IN THE SUPERFICIAL LAYER OF THE BACK. (Gerrish.)

These muscles end at different levels by a series of steps, as it were. As the muscle climbs up the back it does not relinquish

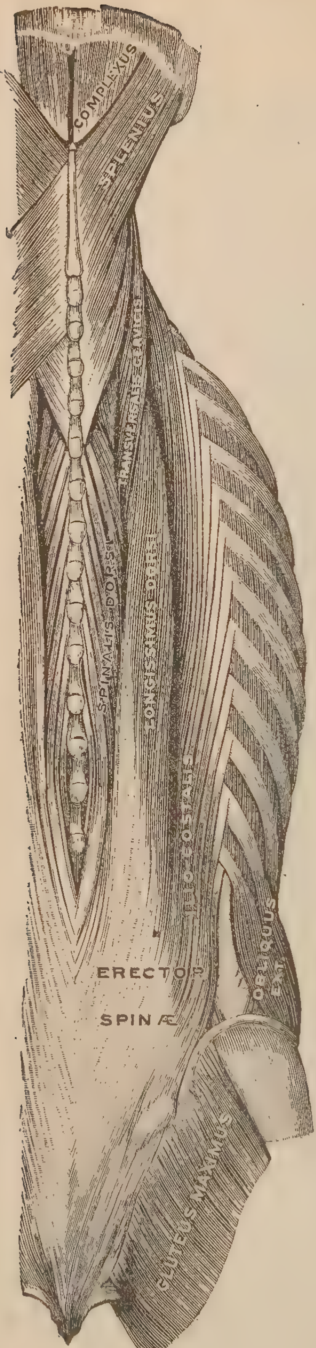


FIG. 80. — ERECTOR SPINÆ, SUPERFICIAL VIEW. (Gerrish.)

one foothold before it establishes another. The result is not merely a continuity of structure but overlapping, as one segment begins back of the ending of the segment below it.

Action.—The several parts of this muscle have a complex action on the vertebral column, head, ribs, and pelvis. The muscle serves as an extensor of the vertebral column and assists in lateral movement and rotation. Portions of the muscle assist in extension, lateral movement, and rotation of the head. Other portions serve as accessory muscles of inspiration. The whole muscle helps in extension and lateral movements of the pelvis in walking.

Muscles of the chest. — The chief bulk of the anterior muscular wall of the chest is made up of the pectoral and the serratus magnus muscles.

Pectoralis major.—The pectoralis major arises from the sternal end of the clavicle, the sternum, and the six upper ribs. The fibres converging form a thick mass, which is inserted by a tendon of considerable breadth into the upper part of the humerus.

Action. — It draws the arm downward and forward, also rotates it inward.

Pectoralis minor. — The pectoralis minor is underneath and entirely covered by the pectoralis major. It arises from the surface of the third,

fourth, and fifth ribs, near the cartilages, and is inserted in the coracoid[1] process of the scapula.

Action. — It draws the shoulder forward, thus assisting the action of the serratus magnus.

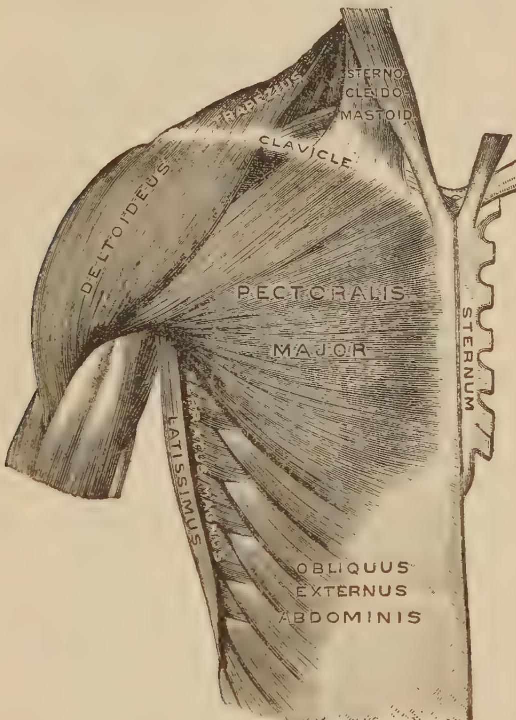


FIG. 81. — FRONT OF CHEST AND SHOULDER OF RIGHT SIDE, SUPERFICIAL MUSCLES. (Gerrish.)

Serratus magnus. — The serratus magnus (serratus anterior) arises from the outer surface of the upper eight or nine ribs several inches back from their front ends. The fibres run upward and backward and are inserted in various portions of the scapula.

Action. — It draws the shoulder forward as in pushing; and the lower segment rotates the apex of the scapula upward, resulting in a tilting upward of the glenoid cavity which facilitates the upward movement of the arm above the head.

Muscles of the thorax. — The muscles of the thorax are chiefly concerned with the movements of the ribs during respiration. They are the: (1) intercostals, and (2) levatores costarum.

[1] See Fig. 54 for coracoid process of scapula.

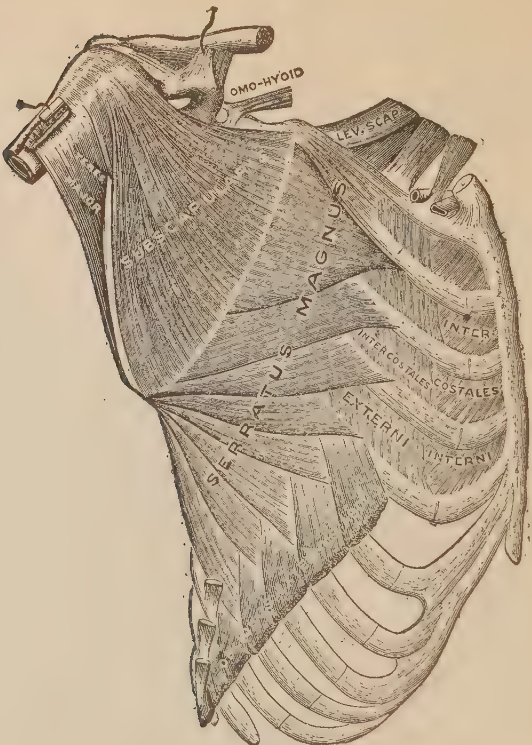


FIG. 82. — SERRATUS MAGNUS OF RIGHT SIDE. The scapula has been turned backward and drawn outward. (Gerrish.)

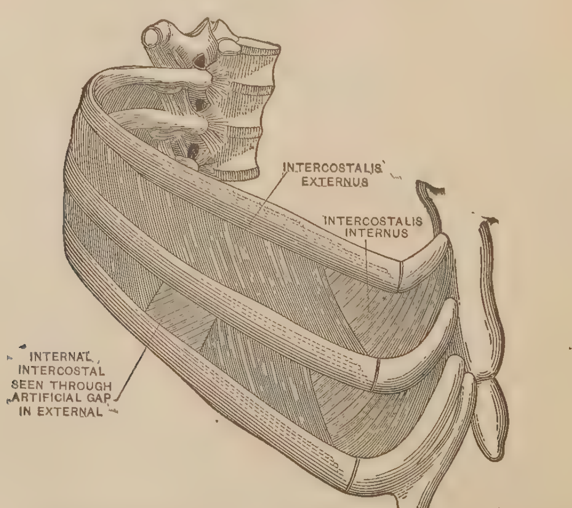


FIG. 83. — INTERCOSTAL MUSCLES IN RIGHT WALL OF THORAX. (Gerrish.)

Intercostals. — The intercostals are found filling the spaces between the ribs. Each muscle consists of two layers, one external and one internal, and as there are eleven intercostal spaces on each side, and two muscles in each space, it follows there are forty-four intercostal muscles. The fibres of these muscles run in opposite directions.

External intercostals. — The external fibres arise from the lower border of a rib, run downward, and inward, toward the mid-line and are inserted into the upper border of the next lower rib.

Action. — They pull the ribs upward and outward, thereby increasing the chest cavity.

Internal intercostals. — The internal fibres arise from the lower border of a rib, run downward, and backward, and are inserted into the upper border of the next lower rib.

Action. — It is considered probable that the internal intercostals act in the same way as the external, although some authorities state that the internal muscles depress the ribs.

Levatores costarum (lifters of the ribs). — The levatores costarum are twelve small slips that arise from the transverse processes of the vertebræ from the seventh cervical to the eleventh thoracic. Each one spreads out in a fan-like manner as it descends to its insertion in the rib below.

Action. — They assist in elevating all the ribs and with other muscles draw the lower ribs backward.

Diaphragm. — The diaphragm is a thin, musculo-fibrous partition which divides the ventral cavity of the body into thoracic and abdominal cavities. It is irregularly dome shaped, its centre being made of a central aponeurotic tendon, to the edges of which muscular tissue is attached which radiates to the circumference of the thorax where it is fastened to the body wall. It has three large openings: for the passage of the aorta, the largest artery of the body; the inferior vena cava, one of the largest veins of the body; and the œsophagus, or gullet; it has also some smaller openings for the passage of blood-vessels, nerves, etc. The upper or thoracic surface of the diaphragm is highly arched; the heart is supported by the central tendinous portion of the arch, the right and left lungs by the lateral portions, the right portion of the arch being slightly higher than the left. The lower or under

surface of the diaphragm is deeply concave, and covers the liver, stomach, pancreas, spleen, and kidneys.

Action. — The diaphragm is probably the most important voluntary muscle in the body, as well as the chief respiratory and expulsive muscle. In the act of inspiration the diaphragm contracts, and in contracting flattens out and descends, the abdominal viscera are pressed downward, and the thorax is expanded verti-

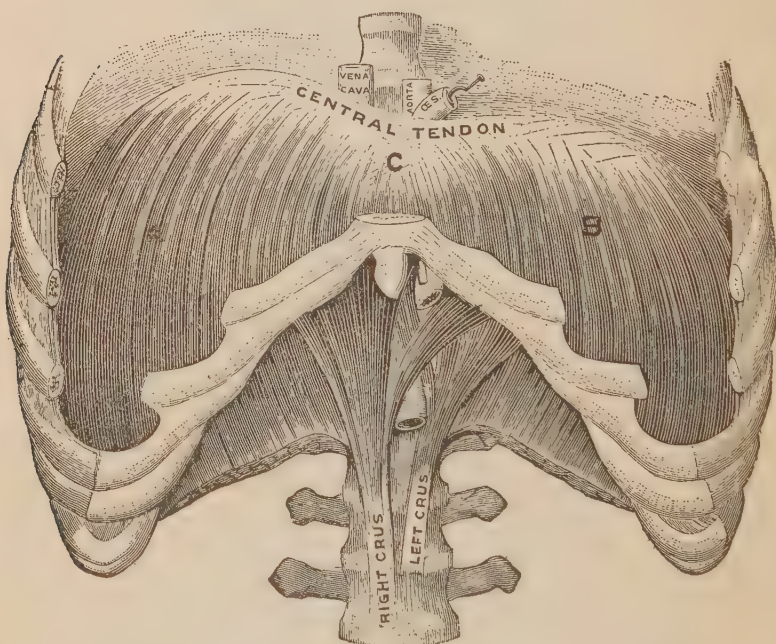


FIG. 84. — DIAPHRAGM. Viewed from in front. (Gerrish.) At *A* the liver and at *B* the cardiac end of the stomach are underneath the diaphragm and push it up; at *C* the tip of the heart pushes the diaphragm down.

cally. In forcible acts of expiration, and in efforts of expulsion from the thoracic and abdominal cavities, the diaphragm and all the other muscles which tend to depress the ribs, and those which compress the abdominal cavity, concur in powerful action to empty the lungs, to fix the trunk, and to expel the contents of the abdominal viscera. Thus it follows that the action of the diaphragm is of assistance in expelling the fœtus from the uterus, the feces from the rectum, the urine from the bladder, and its contents from the stomach in vomiting.

Muscles of the abdomen. — The chief muscles of the abdomen are: (1) external oblique, (2) internal oblique, (3) rectus abdominis, (4) transversalis, and (5) quadratus lumborum. Of these muscles, the rectus is in front, the quadratus is behind, and the contractile portion of the obliquus externus, obliquus internus, and transversalis are at the side.

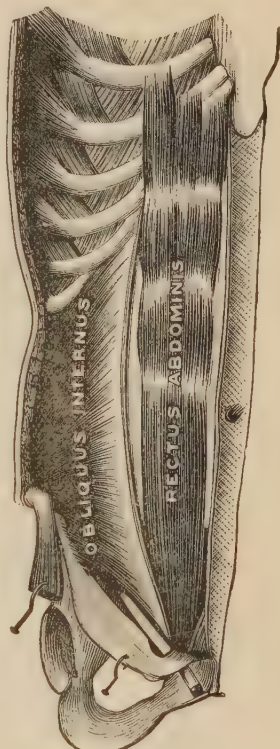


FIG. 85. — RECTUS ABDOMINIS AND OBLIQUUS INTERNUS OF RIGHT SIDE. (Gerrish.)

External oblique. — The strongest and most superficial of the abdominal muscles is the external oblique. It arises from the outer surface of the eight lower ribs. The fibres incline downward and forward and terminate in the broad aponeurosis, which, meeting its fellow of the opposite side in the linea alba, covers the whole of the front of the abdomen. The lowest fibres of the aponeurosis are gathered together in the shape of a thickened band, which extends from the anterior superior spinous process of the ilium to the pubic bone, and forms the well-known and important landmark, the *inguinal ligament*, more commonly known as Poupart's ligament from the anatomist who first described it.

Internal oblique. — The internal oblique muscle lies just beneath the external oblique. It arises from the inguinal ligament, the outer crest of the ilium, and slightly from the lumbar fascia.[1] Its most posterior fibres run upward and forward and are inserted in the costal cartilages of the four lower ribs. At the outer border of the rectus muscle the remaining muscle fibres expand into a broad aponeurosis. This aponeurosis divides into two layers, one passing before, the other behind, the rectus muscle; they reunite at its inner border in the linea alba, and thus form a sheath for the rectus, extending from the xiphoid process to the crest of

[1] The *lumbar fascia* springs from the lumbar and sacral portions of the vertebral column, in three layers.

the pubes. At the lower part of the rectus the posterior layer of the aponeurosis is deficient.

Rectus abdominus. — The rectus is a long, flat muscle, consisting of vertical fibres situated at the fore part of the abdomen, and enclosed in the fibrous sheath formed by the aponeuroses of the internal oblique, the external oblique, and the transversalis muscles. It arises from the pubic bone, and is inserted into the cartilages of the fifth, sixth, and seventh ribs; it is separated from the muscle of the other side by a narrow interval which is occupied by the linea alba.

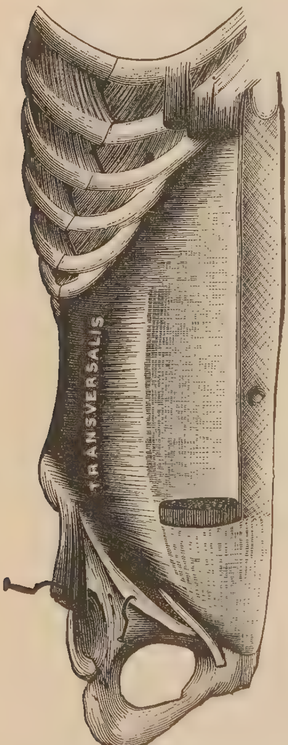


FIG. 86. — TRANSVERSALIS ABDOMINIS OF RIGHT SIDE. (Gerrish.)

Transversalis. — The transversalis muscle lies beneath the internal oblique. The fibres arise from the six lower costal cartilages, the lumbar fascia, the crest of the ilium, and the outer third of the inguinal ligament. The greater part of its fibres have a horizontal direction, and are inserted in the linea alba and the crest of the pubes.

Linea alba. — The linea alba, or white line, is a tendinous band formed by the union of the aponeuroses of the two oblique and transversalis muscles, the tendinous fibres crossing one another from side to side. It extends perpendicularly, in the middle line, from the xiphoid portion of the sternum to the pubes. It is a little broader above than below, and a little below the middle it is widened into a flat, circular space, in the centre of which is situated the umbilicus.

Quadratus lumborum. — The quadratus lumborum is a square, flat muscle which lies toward the back part of the abdominal wall, extending between the crest of the ilium and the lower border of the twelfth rib. (See Fig. 90.)

Action of the abdominal muscles. — When these muscles contract, they compress the abdominal viscera, and constrict the

cavity of the abdomen, in which action they are much assisted by the descent of the diaphragm. By these means they give assistance in parturition, defecation, micturition, and emesis. They also assist in respiration, flex the thorax on the pelvis, and are concerned with lateral bending and rotation at the spine.

The inguinal canal. — Between the abdominal muscles, parallel to, and about one-half inch above the inguinal ligament, is a tiny canal, about one and one-half inches long, called the inguinal canal. The internal opening of the canal is called the *internal abdominal ring,* and is situated in the fascia of the transversalis muscle, midway between the spine of the ilium and the crest of the pubic bone. The canal ends in the *external abdominal ring,* which is in the tendon of the external oblique muscle. This canal transmits the spermatic cord in the male, and the round ligament of the uterus in the female.

Weak places in the abdominal walls. — The *internal* and *external abdominal rings,* described above, the *umbilicus,* and another ring situated just below the inguinal ligament, and called the *femoral ring,* are considered weak places because they are so often the seat of *hernia.* Hernia,[1] or rupture, is a protrusion of a portion of the contents of a body cavity, and in this instance would mean a protrusion of a portion of the intestine or mesentery through one of these weak places. If it occurs in the umbilicus, it is called *umbilical hernia;* in the inguinal rings, *inguinal hernia;* and in the femoral ring, *femoral hernia.* The inguinal canal is larger in the male than in the female, hence inguinal hernia is more common in the male than in the female.

MUSCLES OF THE UPPER EXTREMITIES

A certain number of muscles situated superficially on the trunk are frequently grouped with the muscles of the upper extremities, as their function is to attach the upper limbs to the trunk and move the shoulders and arms. Of these, the two superficial muscles we have mentioned as covering the back, and the muscles covering the front of the chest, are the chief.

The muscles of the extremities are arranged in antagonistic

[1] If the skull is injured so that a portion of the brain protrudes, it would also be correctly spoken of as hernia of the brain. Of course this is more unusual than abdominal hernia.

groups, the action of one group opposing the action of the other. The movements of which the extremities are capable are flexion and extension, abduction and adduction, supination and pronation, circumduction and rotation. (See page 94.)

Functionally we may group the muscles of the upper extremities as follows: —

	Name of Muscle	Location	Function
Moving the Shoulder	Trapezius	Upper portion of back	Moves shoulder upward, backward, and inwardly rotates the scapula.
	Pectoralis minor	Chest, under pectoralis major	Moves shoulder forward, thus assisting action of serratus magnus.
	Serratus magnus	Upper two-thirds of side of chest	Moves shoulder forward and rotates apex of scapula upward.
Moving the Arm	Deltoid	Covers the top of the shoulder	Abduction, forward and backward motion.
	Pectoralis major	Chest, from sternum to humerus	Adduction, forward motion and inward rotation.
	Latissimus dorsi	Lower portion of back	Adduction, and rotates the humerus inward.
Moving the Forearm	Biceps	Anterior surface of arm	Flexes the elbow joint and supinates the forearm.
	Triceps	Posterior surface of arm	Extension.
	Pronators	Anterior surface of forearm	Pronation.
	Supinators	Posterior surface of forearm	Supination

Deltoid. — The deltoid is a coarse, triangular muscle covering the top of the shoulder. It arises from the clavicle, acromion process, and spine of the scapula, extends downward, and is inserted into the middle of the shaft of the humerus, on the outer side. (See Fig. 81.)

Action. — It abducts — raises the arm from the side so as to bring it at right angles to the trunk, also draws the arm forward

and backward. This action is opposed by the pectoralis major and the latissimus dorsi, which have been described.

Biceps. — The biceps is a long fusiform muscle, occupying the whole of the anterior surface of the arm; it is divided above into two portions or heads, from which circumstance it has re-

FIG. 87. — MUSCLES OF THE FRONT OF THE RIGHT SHOULDER AND ARM. (Gerrish.)

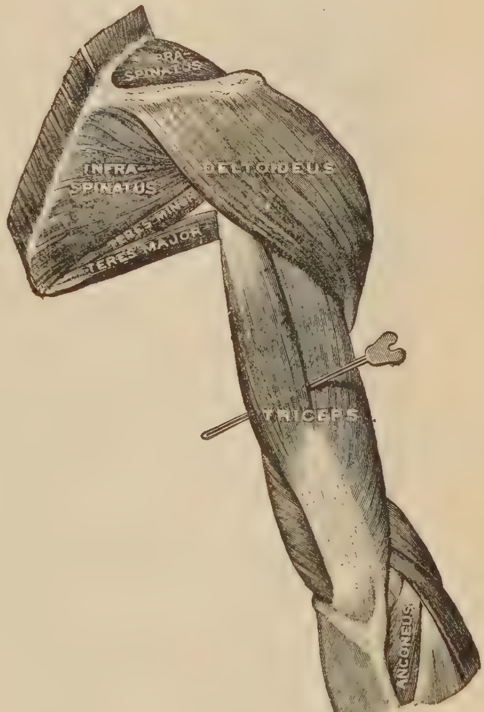


FIG. 88. — MUSCLES ON THE DORSUM OF THE RIGHT SHOULDER AND ARM. (Gerrish.)

ceived its name. It arises by these two heads from the scapula, and is inserted into the radius.

Action. — The action of the biceps is complex, as it affects three joints. The muscle raises and draws forward the humerus at the shoulder joint, flexes the elbow joint, and supinates the forearm. The combination of these movements produces a simple act, *e.g.*, raising the hand to the mouth.

Triceps. — The triceps is situated on the back of the arm, extending the whole length of the posterior surface of the humerus.

It is of large size, and divided above into three heads; hence its name. Two of the heads have their origin in the scapula and one in the humerus. The three heads unite in a common tendon which is inserted into the ulna.

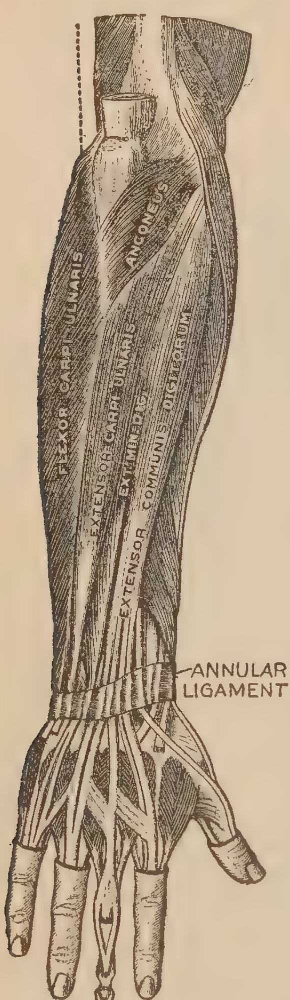


FIG. 89. — MUSCLES IN THE DORSUM OF THE RIGHT FORE-ARM AND HAND. (Gerrish.)

Action. — It is the great extensor muscle of the forearm, and is the direct antagonist of the biceps.

Muscles of the forearm. — The muscles covering the forearm are disposed in groups, the **pronators** and **flexors** being placed on the front and inner part of the forearm, and the **supinators** and **extensors** on the outer side and back of the forearm: they antagonize one another. The pronators turn the palm of the hand backward and, when the elbow is flexed, downward or prone. The supinators turn the palm of the hand forward, and, when the elbow is flexed, upward or into the supine position. The flexors and extensors have long tendons, some of which are inserted into the bones of the wrist, and some into the bones of the fingers: they serve to flex and extend the wrist and fingers.

MUSCLES OF THE LOWER EXTREMITIES

If we compare the muscles of the shoulder, arm, and forearm with those of the hip, thigh, and leg, we shall see that the anterior muscles of the former correspond roughly with the posterior muscles of the latter, the muscles of the hip, thigh, and leg, however, being larger and coarser in texture than those of the shoulder, arm, and forearm.

Functionally we may group the most important muscles of the lower extremities as follows: —

	Name of Muscle	Location	Function
Moving the Thigh	Psoas magnus Iliacus	In the pelvis and upper part of thigh	*Flexion*, outward rotation and, according to some authors, inward rotation.
	Gluteus maximus	Region of buttocks	*Extension*, outward rotation and adduction.
	Gluteus medius	Under gluteus maximus	*Abduction* and inward rotation.
	Gluteus minimus	Under gluteus medius	
	Adductor magnus	Mesial part of thigh	*Adductor* and *extensor*
	Adductor longus		*Adducts* and assists in flexing the thigh
	Adductor brevis		*Adducts* and flexes the thigh.
	Adductor gracilis		*Adducts* thigh and flexes the leg.
Moving the Leg	Sartorius	Front of thigh	*Flexes* the hip and knee joints, everts thigh, and assists in rotation of tibia.
	Biceps Semitendinosus Semimembranosus	Hamstring Back of thigh	*Flexors* of knee, rotate leg, and extend thigh.
	Rectus femoris Vastus externus Vastus internus Vastus intermedius	Quadriceps Front of thigh	*Extension of* leg, flexes the thigh
Moving the Foot	Tibialis anterior Peroneus tertius	Front of leg	*Flexes* the ankle
	Tibialis posterior	Back of leg	*Extensor* of ankle
	Gastrocnemius		*Flexes* knee and *extends* ankle
	Soleus		*Extensor* of ankle
	Peroneus longus Peroneus brevis	Outer part of leg	*Extensors*

Psoas magnus. — The great loin muscle arises from the last thoracic and all the lumbar vertebræ with the included inter-

vertebral cartilages. It extends downward and forward, then downward and backward, to its insertion in the small trochanter of the femur.

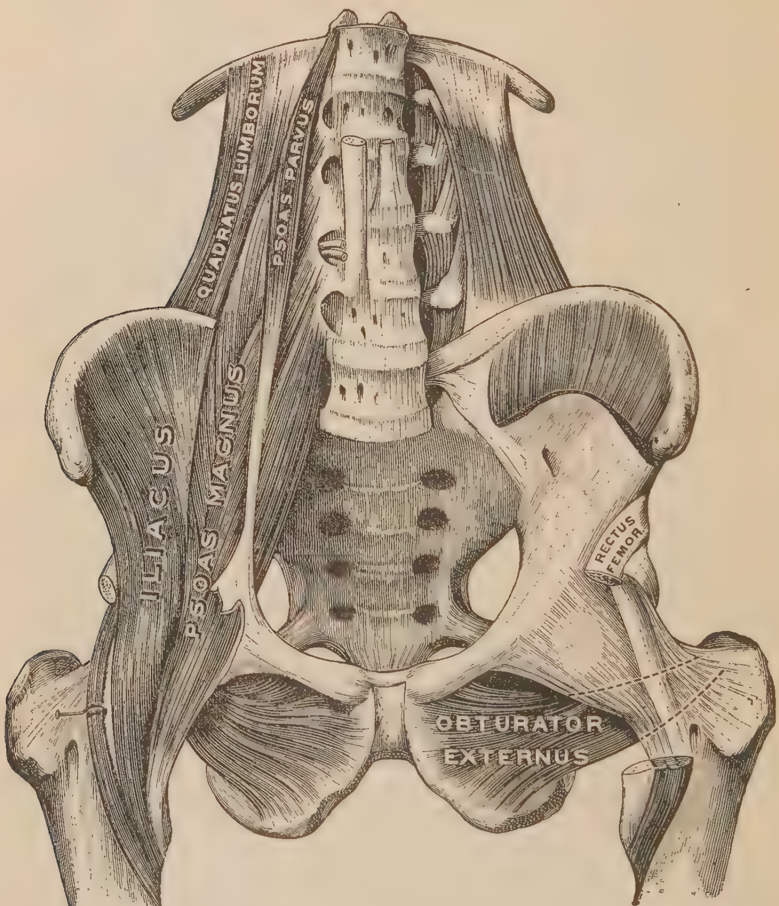


FIG. 90.—PSOAS, ILIACUS, AND OBTURATOR EXTERNUS MUSCLES. (Gerrish.)

Iliacus.—This muscle and its relation to the psoas magnus is well shown in Fig. 90. It arises from the iliac fossa and is inserted partly into the tendon of the psoas and partly into the small trochanter of the femur.

Action.—The psoas magnus and iliacus act as one muscle to flex the thigh on the pelvis, and rotate the femur outward or according to some authors, inward.

Glutei muscles. — The three gluteal muscles are coarse in texture, and form the chief prominence of the buttocks.

Gluteus maximus arises from the ilium, sacrum, and coccyx, and is inserted into the great trochanter of the femur.

Action. — It is a powerful extensor of the hip-joint. It also rotates the femur outward, and adducts the thigh.

Gluteus medius and gluteus minimus are under the gluteus maximus and almost entirely covered by it. They arise from the outer surface of the ilium and are inserted into the great trochanter.

Action. — Abduction of the thigh, and inward rotation.

FIG. 91. — GLUTEUS MAXIMUS OF RIGHT SIDE. (Gerrish.)

Adductors. — The four adductor muscles are called respectively *magnus* (great), *longus* (long), *brevis* (short), and *gracilis* (slender). They are situated on the inner side of the thigh. They arise from different portions of the pubic bone, and the first three are inserted into the inner side of the femur. The gracilis is inserted into the shaft of the tibia.

Action. — The magnus adducts and extends the thigh; the longus and brevis adduct and flex the thigh. The gracilis adducts the thigh and flexes the leg.

Sartorius. — The sartorius, or tailor's muscle, is a long, ribbon-like muscle situated on the front of the thigh. It crosses the thigh obliquely from its origin in the ilium to its insertion in the tibia. It was formerly supposed to be the muscle principally concerned in producing the posture assumed by the tailor in sitting cross-legged, hence its name.

Action. — It flexes the hip and knee joints, everts the thigh, and assists in rotation of the tibia.

Biceps. — The biceps arises by two heads, one from the ischium, and the other from the posterior surface of the femur. It is in-

serted into the head of the fibula and the outer tubercle of the tibia.

Semitendinosus and Semimembranosus. — They arise from the ischium, and are inserted into the upper and inner part of

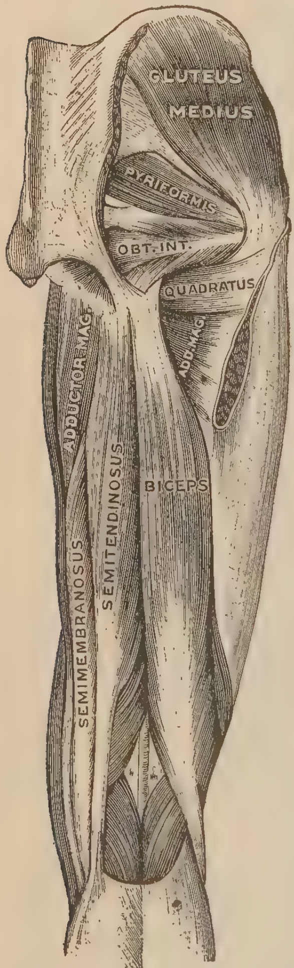


FIG. 92. — MUSCLES IN THE DORSUM OF THE RIGHT THIGH. (Gerrish.)

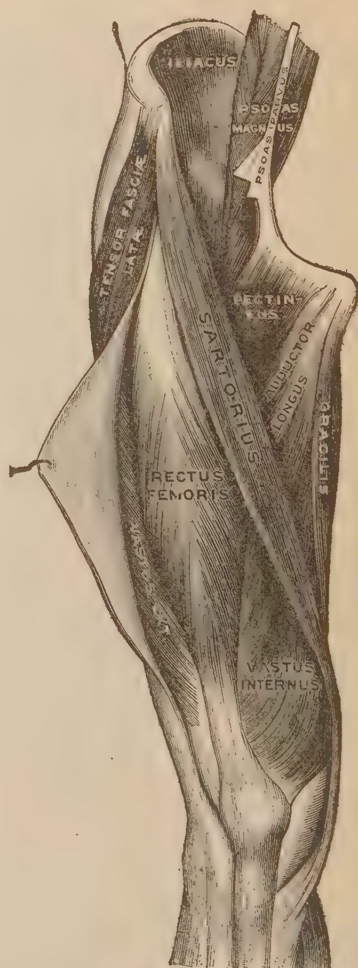


FIG. 93. — SUPERFICIAL MUSCLES IN FRONT PART OF THE RIGHT THIGH. (Gerrish.)

the tibia. These three muscles, the biceps, semitendinosus, and semimembranosus, cover the back of the thigh, hence are named *posterior femoral,* or hamstring muscles.

Action. — They flex the knee, rotate the leg, and extend the thigh.

Quadriceps. — The quadriceps is a four-headed muscle that covers the front of the thigh, and is analogous to the triceps covering the back of the arm. Each head is described as a separate muscle: (1) rectus femoris, (2) vastus externus, (3) vastus internus, (4) vastus intermedius.

FIG. 94. — VASTUS INTERMEDIUS OF RIGHT SIDE. (Gerrish.)

FIG. 95. — GASTROCNEMIUS OF RIGHT SIDE. (Gerrish.)

The rectus femoris arises from the ilium, the other three arise from the femur. They pass downward, and are inserted by one tendon into the tubercle of the tibia. The tendon passes in front of the knee-joint, and the patella is a sesamoid bone developed in it.

Action. — The quadriceps is the great extensor of the leg; it

also flexes the thigh, and antagonizes the action of the hamstring muscles.

Gastrocnemius and soleus. — The gastrocnemius and soleus form the calf of the leg. The gastrocnemius arises by two heads from the two condyles of the femur. The soleus is in front of the gastrocnemius. It arises from the tibia and fibula. The direction of both is downward, and they are inserted into a common tendon, the tendon of the heel (tendo Achillis), which is the thickest and strongest tendon in the body, and is inserted into the calcaneum, or heel bone.

Action. — The gastrocnemius flexes the knee, extends the ankle, and is responsible for the spring in the gait at the end of a step. The muscle is a powerful one and should be capable of raising about twice the weight of the body. The soleus is a powerful extensor of the ankle.[1]

[1] Additional muscles included in Summary.

SUMMARY

Muscular tissue	Cells become elongated. Intercellular substance which is at a minimum. Connective tissue — supporting framework. Well supplied with nerves and blood-vessels.
Classification	1. Striated, voluntary, skeletal. 2. Non-striated, involuntary, visceral. 3. Cardiac.
Striated { Voluntary, Skeletal	1. Marked with transverse striæ. 2. Under control of will. 3. Attached to skeleton. 4. Composed of bundles of multinuclear elongated cells. 5. Reticular tissue framework. 6. Attached to bones, cartilage, ligaments, skin by means of *tendons*. 7. One muscle connects with another by means of an *aponeurosis*. 8. Muscles closely covered by sheets of fascia. 9. Deep fasciæ form annular ligaments in vicinity of wrist and ankle. 10. Origin — more fixed attachment. 11. Insertion — more movable attachment.
Non-striated { Involuntary, Visceral	1. Not marked with transverse striæ. 2. Not under control of will. 3. Found in walls of blood-vessels and viscera. 4. Composed of bundles of elongated cells that contain just one nucleus. 5. Reticular tissue framework.
Cardiac { Striated, Involuntary, Visceral	1. Striated but not distinctly. 2. Not under control of will. 3. Made up of short cells, that contain one nucleus, no sarcolemma. 4. Cells grouped in square bundles. 5. Fine fibrils from cells form a supporting network. 6. Reticular tissue framework.
Characteristics of muscular tissue	1. Irritability — response to a stimulus. 2. Contractility — muscle becomes shorter and thicker. 3. Extensibility — muscle can be stretched. 4. Elasticity — muscle readily returns to original shape. 5. Tonicity — mild, sustained contraction.
Function	Contraction. On this muscular activity depends.

Stimuli
- Term used to describe influences which irritate or stimulate.
- Varieties
  1. Chemical.
  2. Mechanical.
  3. Thermal.
  4. Electrical.
  5. Nervous — important one.

heat cold tr[illegible]

Varieties of Muscular Movements
- Voluntary — stimuli from central nervous system.
- Involuntary — automatic
- Cardiac — automatic
  - (Involuntary and Cardiac) Stimuli from nervous system increase or decrease activity.

Nerves
- Afferent — Carry impulses *from* periphery to brain, spinal cord, or ganglia.
  - Afferent nerves connected with muscles are spoken of as sensory.
- Efferent — Carry impulses *to* the periphery from brain, spinal cord, or ganglia.
  - Efferent nerves that end in muscles are spoken of as motor.

Conditions of Contraction
- Skeletal muscle — contracts quickly, relaxes promptly.
- Visceral muscle — contracts slowly, maintained for some time, fades out slowly.
- Heart muscle — contracts and relaxes unceasingly during life.
- Contractions
  - Result of series of rhythmic stimuli.
  - Consist of
    - Latent period . .01 sec.
    - Contraction period .04 sec.
    - Relaxation period .05 sec.
- Tetanus — compound contraction, due to stimuli being received too rapidly to allow for periods of relaxation.

Source of Energy
- Well supplied with blood from which glycogen is obtained and stored.
- *Glycogen* represents potential energy.
- *Stimuli* transform potential energy to mechanical energy.
- Chemical Change
  - Oxidation of glycogen and perhaps fat.
  - Waste substances
    - Carbon dioxide
    - Water
    - Lactic acid

Foods? nourishment

Fatigue
- Loss of nutritive materials.
- Accumulation of waste substances.

FUNCTIONALLY IMPORTANT MUSCLES

Name of Muscle and Where Found		Origin	Insertion	Function
Head				
Occipito-frontalis	Occipital	Occipital bone	Aponeurosis — top of skull	Elevate the eyebrows, cause transverse wrinkles of forehead.
	Frontal	Tissues of the eyebrows	Aponeurosis — top of skull	
Face				
Orbital Muscles.	Superior rectus	Apex of orbit	Upper and central portion of eyeball	Rolls the eyeball upward.
	Inferior rectus	Apex of orbit	Lower and central portion of eyeball	Rolls the eyeball downward.
	Internal rectus	Apex of orbit	Midway on inner side of eyeball	Rolls the eyeball to which it is attached inward, the opposite one outward.
	External rectus	Apex of orbit	Midway on outer side of eyeball	Rolls the eyeball to which it is attached outward, the opposite one inward.
	Superior oblique	Apex of orbit	Eyeball — between superior and external recti	Rolls the pupil downward and outward.
	Inferior oblique	Orbital plate of maxilla	Eyeball — near external recti	Rolls the pupil upward and outward.
	Levator palpebræ superioris	Sphenoid bone	Tarsal cartilage of upper lid	Elevates upper lid and opens eye.

Name of Muscle and Where Found		Origin	Insertion	Function
Muscles of Mastication	Masseter	Zygomatic process of malar bone	Mandible	Raises the mandible and closes the mouth
	Temporal	Temporal bone	Mandible	Raises the mandible and closes the mouth. Draws the mandible backward.
	Internal pterygoid	Sphenoid, palate, and maxilla	Mandible	Closes the mouth. Moves jaw forward and sideways.
	External pterygoid	Sphenoid bone	Mandible	Moves the jaw forward and sideways.
Muscles of Expression	Orbicularis oris	Partition between nostrils and maxillæ	Mandible	Closes the lips. Sphincter of mouth.
	Buccinator	Alveolar processes of maxilla and mandible	Orbicularis oris	Flattens the cheeks, brings them in contact with the teeth.
Muscles of the Tongue	Genioglossus	Front part of mandible	Whole length of tongue in and at the side of the midline	Thrusts the tongue forward, retracts it, and also depresses it.
	Styloglossus	Styloid process of temporal bone	Whole length of side and under part of tongue	Retracts the tongue and depresses it.
Muscles of the Neck	Platysma	Skin and fascia of the pectoral, deltoid, and trapezius muscles	Mandible and muscles about the angle of the mouth	Depresses the mandible and laterally flexes the head.
	Sterno-cleido-mastoid	Sternum and clavicle	Mastoid portion of temporal bone	Both acting together flex the head on the chest or neck, and serve as extraordinary muscles of respiration.

Name of Muscle and Where Found		Origin	Insertion	Function
	Muscles of the Trunk			
Muscles of the Back	Trapezius	Occipital bone, ligamentum nuchæ, and spinous processes of the last cervical and all the thoracic vertebræ	Clavicle, acromion process, and spine of scapula	Upper fibres raise shoulder. Middle fibres adduct the scapula. Lower fibres rotate lower angle of the scapula toward the median line.
	Latissimus dorsi	Last six thoracic vertebræ, lumbar, and sacral part of spine and crest of ilium	Front of the humerus	Draws the arm to the side, draws it downward and backward, and rotates the humerus inward.
	Erector Spinæ Outer Division: Ilio-costalis Accessorius and ilio-costalem Cervicalis ascendens Middle Division: Longissimus dorsi Transversalis cervicis Trachelo-mastoideus Inner Division: Spinalis dorsi	Lower and back part of sacrum, back portion of the ilia, and spines of the lumbar vertebræ	At different levels of the spinal column, from the lower ribs to the cervical vertebræ and mastoid processes of the temporal bones	Serves as an extensor of the vertebral column and assists in lateral movement and rotation. Portions of the muscle assist in extension, lateral movement, and rotation of the head. Other portions serve as accessory muscles of inspiration. The whole muscle helps in extension and lateral movements of the pelvis in walking.
Chest	Pectoralis major	Clavicle, sternum, and cartilages of six upper ribs	Upper part of humerus	It draws the arm downward and forward, also rotates it inward.
	Pectoralis minor	Outer surfaces of 3d, 4th, and 5th ribs	Scapula	Draws the shoulder forward.
	Serratus Magnus	Outer surface of upper eight or nine ribs	Various portions of the scapula	Draws shoulder forward as in pushing, and the lower segment rotates the axis of the scapula upward.

Name of Muscle and Where Found		Origin	Insertion	Function
Thorax	External intercostals	Arise from lower border of each upper rib	Upper border of each lower rib	Pulls the ribs upward and outward.
	Internal intercostals	Arise from lower border of each upper rib	Upper border of each lower rib	Action may be the same as the external or may depress the ribs.
	Levatores costarum	Transverse processes of vertebræ from 7th cervical to the 11th thoracic	Outer surface of the ribs between the tubercles and angles	Assist in elevation of the ribs and with other muscles draw the lower ribs backward.
	Diaphragm	Internal circumference of the thorax	A central aponeurotic tendon	Modifies size of chest and abdominal cavity. Aids in expulsion.
Abdomen	External oblique	Outer surface of lower eight ribs	Outer lip of iliac crest, pubic spine and crest, the iliopectineal line, front of the symphysis and the linea alba	Compression of abdominal viscera, rotation of the pelvis to the same side, and flexion of the pelvis on the chest.
	Internal oblique	Inguinal ligament, outer crest of the ilium, and the lumbar fascia	Costal cartilages of four lower ribs, end of sternum, linea alba, and crest of pubis	Compresses the abdominal viscera, depresses the ribs, and flexes the chest upon the pelvis.
	Rectus abdominis	Pubic bone	Costal cartilages of 5th, 6th, and 7th ribs	Depression of the thorax and compression of the abdominal viscera.
	Transversalis	Lower six costal cartilages, lumbar fascia, crest of ilium, and outer third of the inguinal ligament	Linea alba and crest of the pubis	Compression of the abdominal viscera.
	Quadratus lumborum	Crest of the ilium, and transverse processes of several lumbar vertebræ	Twelfth rib and transverse processes of several lumbar vertebræ	Bends the lumbar portion of the spine laterally. Draws last rib downward.

Name of Muscle and Where Found			Origin	Insertion	Function
Upper Extremity		Deltoid	Clavicle, acromion process, and spine of scapula	Middle of shaft of humerus	Raises the arm from the side, also draws it forward and backward.
		Biceps	Scapula	Radius	Raises and draws forward the humerus at the shoulder joint, flexes the elbow joint, and supinates the forearm.
		Triceps	Scapula and posterior surface of the humerus	Ulna	Extension of forearm.
	Pronators	Pronator teres (front of forearm)	Humerus and ulna	Radius	Pronation of the hand.
		Pronator quadratus (lower quarter, front of forearm, close to the bones)	Inner and lower portion of ulna	Front and lower fourth of radius	Pronation of the hand.
	Flexors	Flexor carpi radialis (front of forearm)	Humerus	Base of 2d metacarpal bone on its palmar aspect	Flexion and slight pronation of hand.
		Flexor palmaris longus (front of forearm)	Humerus	Palmar fascia and anterior annular ligament	Tightens the fascia of the palm, then flexes the hand.
		Flexor carpi ulnaris front and inner border of forearm)	Humerus and ulna	Pisiform, unciform, and base of 5th metacarpal	Flexion of the hand.
	Supinators	Brachio-radialis or long supinator (outer and front part of lower fourth of arm and forearm)	Humerus	Lower portion of radius	Flexion of forearm and supination of hand.
		Supinator brevis (deep in upper third of outer part of forearm)	External condyle of humerus	Radius	Supination.

Name of Muscle and Where Found			Origin	Insertion	Function
Upper Extremity	Extensors	Extensor carpi radialis longus (outer border of forearm)	Humerus	2d metacarpal bone	Extension of hand.
		Extensor carpi radialis brevis (outer border of forearm)	Humerus	3d metacarpal bone	Extension of hand.
		Extensor carpi ulnaris	Humerus and ulna	5th metacarpal bone	Extension of the hand.
Lower Extremity		Psoas magnus (in the pelvis and upper part of thigh)	Last thoracic and all the lumbar vertebræ with included intervertebral cartilages	Small trochanter of femur	Flexion and external or internal rotation of thigh.
		Iliacus	Iliac fossa	Partly in tendon of psoas, and partly in small trochanter of femur	Same as psoas magnus.
		Gluteus maximus (largest)	Ilium, sacrum, and coccyx	Great trochanter of femur	Extension of the hip joint, external rotation, and abduction of the thigh.
		Gluteus medius (middle)	External surface of the ilium	Great trochanter of femur	Abduction of the thigh, and inward rotation.
		Gluteus minimus (smallest)	External surface of the ilium	Great trochanter of femur	Abduction of the thigh, and inward rotation.
	Internal Femoral	Adductor magnus	Pubic arch and ischium	Inner side of femur	Adducts and extends the thigh.
		Adductor longus	Pubic bone	Inner side of femur	Adducts and flexes the thigh.
		Adductor brevis	Upper part of pubic arch	Inner side of femur	Adducts and flexes the thigh.
		Adductor gracilis	Lower part of pubic arch	Inner side of femur	Adducts thigh and flexes the leg.

		Name of Muscle and Where Found	Origin	Insertion	Function
Lower Extremity	Anterior Femoral	Quadriceps arises by four heads: —			
		1. Rectus femoris	Ilium	Tibia	Extend the leg and flex the thigh.
		2. Vastus externus	Femur		
		3. Vastus internus	Femur		
		4. Vastus intermedius	Femur		
		Sartorius (front and inner side of thigh between ilium and tibia)	Anterior superior iliac spine	Inner surface of the tibia	Flexes the hip and knee joints. Everts the thigh and assists in rotation of the tibia.
	Posterior Femoral	Biceps	Ischium and femur	Fibula and tibia	Flex the knee, rotate the leg and extend the thigh.
		Semitendinosus	Ischium	Tibia	
		Semimembranosus	Ischium	Tibia	
	Flexors	Tibialis anterior (front and outer side of leg)	Tibia and interosseous membrane	Internal cuneiform and 1st metatarsal bone	Flexion of the foot and adduction of its distal end.
		Peroneus tertius (front of leg, dorsum of foot)	Fibula and interosseous membrane	5th metatarsal bone	Flexion of the foot and abduction of its distal end.
	Extensors	Tibialis posterior (back of leg and inner part of foot)	Tibia and fibula	Scaphoid, three cuneiform, cuboid, 2d, 3d, and 4th metatarsal bones	Extension of the foot and abduction of its distal end.
		Peroneus longus (outer side of leg and sole of foot)	Tibia and fibula	Base of 1st metatarsal and internal cuneiform bones	Extension of the foot and abduction of its distal end.
		Peroneus brevis (outer side of leg and foot)	Fibula	5th metatarsal bone	Extension of the foot and abduction of its distal end.
		Gastrocnemius	Femur	Tuberosity of the calcaneum	Flexes the knee and extends the ankle.
		Soleus	Fibula and tibia	Tuberosity of the calcaneum	Same as gastrocnemius.

CHAPTER VIII

SPECIAL MEMBRANES AND GLANDS

MEMBRANE

THE word *membrane* in its widest sense is used to designate any thin expansion of tissue. In a restricted, although the commonest sense, the word *membrane* is used to denote an enveloping or a lining tissue of the body.

Classification of membranes. — The chief membranes of the body are classified as follows: —

1. Serous.
2. Synovial.
3. Mucous.
4. Cutaneous.

SEROUS MEMBRANES

Serous membranes are thin, transparent, tolerably strong, and elastic. The surfaces are moistened by a fluid resembling serum, from which the membranes obtain their name of serous membranes. They are found lining closed cavities and passages that do not communicate with the exterior. They consist of two layers only: (1) endothelium, (2) corium.

(1) *Endothelium* is the name given to a variety of epithelium found lining (*i.e.*, lying within) certain parts of the body. It consists of a single layer of flattened transparent cells joined edge to edge so as to form a smooth membrane.

(2) The *corium* consists of a thin layer of fibrous tissue, and contains blood-vessels, lymph-vessels, and lymphoid tissue.

Serous membranes are attached to the underlying parts by areolar tissue, called *subserous* tissue. They may be divided into three classes: —

(1) Serous membranes proper.
(2) The lining membrane of the vascular system.
(3) The lining membrane of certain cavities.

(1) **Serous membranes proper.** — With one exception, these membranes form closed sacs, one part of which is attached to the walls of the cavity which it lines, — the *parietal* portion, — whilst the other is reflected over the surface of the organ or organs contained in the cavity, and is named the *visceral* portion of the membrane. In this way the viscera are not contained within the sac, but are really placed outside of it, and some of the organs may receive a complete, while others receive only a partial, or scanty, investment.

This class of serous membranes includes: —

(*a*) *The two pleuræ*, which cover the lungs and line the chest.

(*b*) *The pericardium*, which covers the heart, and lines the outer fibrous pericardium.

(*c*) *The peritoneum*,[1] which lines the abdominal cavity, clothes its contained viscera, and also the upper surface of some of the pelvic viscera.

(2) **The lining membrane of the vascular system.** — This applies to the internal coat of the heart, blood-vessels, and lymphatics. It bears a close resemblance to the serous membranes in structure and appearance.

(3) **The lining membrane of certain cavities**: —

(*a*) One illustration of this is the capsule of Tenon. This capsule is a shut sac placed back of the eyeball, with a visceral layer upon the globe of the eye, and the parietal layer next to the bed of fat on which the eyeball rests.

(*b*) The brain and spinal cord enclose cavities which are lined with a delicate serous membrane. One of the membranes that envelop the brain and spinal cord (arachnoid) presents all the elements of a serous membrane, and is properly considered as one.

Function of serous membranes. — The most important function of serous membrane is protection, which is accomplished in two ways: (1) by forming a smooth, slippery lining or covering for the blood-vessels, cavities, and viscera with which it is associated, and (2) by secreting serum which acts as a lubricating fluid and tends to lessen friction.

[1] The peritoneum in the female is the one exception to the rule that serous membranes are perfectly closed sacs, as it has two openings by which the *Fallopian* (uterine) tubes communicate with its cavity.

The inner surface of a serous membrane is free, smooth, and polished; and in the case of serous membranes proper, the inner surface of one part is applied to the corresponding inner surface of some other part, only a very small quantity of fluid being interposed between the surfaces. The organs situated in a cavity lined by a serous membrane, being themselves also covered by it, can thus glide easily against its walls or upon each other, their motions being rendered smoother by the lubricating fluid.

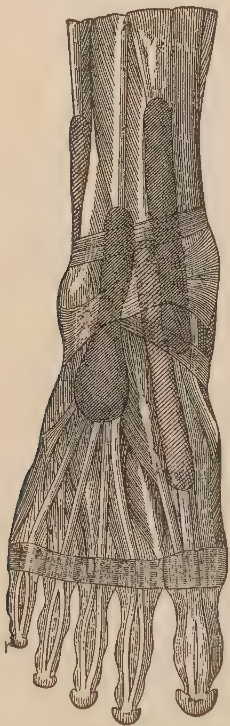


FIG. 96. — THE ANTERIOR ANNULAR LIGAMENT OF THE ANKLE AND THE SYNOVIAL MEMBRANES OF THE TENDONS BENEATH IT. Artificially distended. (Gerrish.)

SYNOVIAL MEMBRANES

Synovial membranes are frequently classed as serous membranes, because their function is the same and they have no communication with the surface of the body. They differ, however, (1) in the nature of their secretion, (2) in their structure, and (3) they are associated with the bones and muscles, and not with the viscera. Synovial membrane is composed of fibrous tissue which has on its free surface an imperfect covering of cells that are irregularly shaped, and secrete a viscid glairy fluid that resembles the white of egg, and is named *synovia.*

They are divided into the following classes: —

1. Articular.
2. Vaginal.
3. Bursal.

1. **Articular.** — Articular synovial membranes are found surrounding and lubricating the cavities of the movable joints in which the opposed surfaces glide on each other.[1]

2. **Vaginal.** — Vaginal synovial membranes are found forming sheaths for the tendons of some of the joints, and thus facilitating their motion as they glide in these fibrous sheaths which bind them down against the bones.

[1] See Fig. 69.

3. **Bursal.** — Bursal synovial membranes, or synovial bursæ, are found in the form of simple sacs, interposed, to prevent friction, between two surfaces which move upon each other. These bursæ may be either *deep-seated,* or *subcutaneous.* The deep-seated are for the most part placed between a muscle and a bone, or between a tendon and a bone. The subcutaneous bursæ lie immediately under the skin, and occur in various parts of the body, interposed between the skin and some firm prominence beneath it. The large bursa, situated over the patella, is a well-known example of this class, but similar, though smaller, bursæ are found also over the olecranon, the malleoli, the knuckles, and other prominent parts.

Function of synovial membranes. — As previously stated, the function of synovial membranes is similar to that of serous membranes, but synovial membranes are associated with the bones and muscles.

MUCOUS MEMBRANES

The mucous membranes, unlike the serous membranes, line passages and cavities which communicate with the exterior. Their surfaces are coated over and protected by mucus, from which the membrane derives its name. The mucous membranes of different parts are continuous, and they may nearly all be reduced to two great divisions; namely, (1) gastropulmonary, and (2) the genito-urinary.

(1) **Gastropulmonary.** — The gastropulmonary mucous membrane covers the inside of the alimentary canal, the air-passages, and the cavities communicating with them. It commences at the edges of the lips and nostrils, proceeds through mouth and nose to the throat, and thence is continued throughout the entire length of the alimentary canal to the anus. At its origin and termination it is continuous with the external skin. It also extends throughout the trachea, bronchial tubes, and air-sacs. From the interior of the nose the membrane is prolonged into the frontal, ethmoidal, sphenoidal, and maxillary sinuses, also into the lacrimal passages, and under the name of conjunctival membrane, over the fore part of the eyeball and inside of the eyelids, on the edges of which it again meets with the skin. From the upper and back part of the pharynx a prolongation ex-

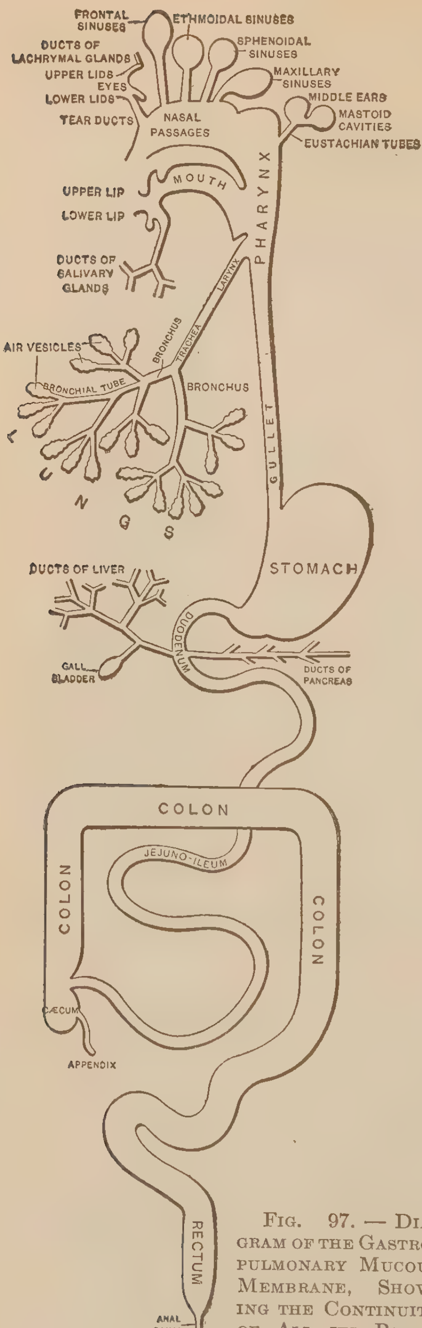


FIG. 97. — DIAGRAM OF THE GASTRO-PULMONARY MUCOUS MEMBRANE, SHOWING THE CONTINUITY OF ALL ITS PARTS. (Gerrish.)

tends on each side, along the passage to the ear, — Eustachian tube,[1] — and offsets in the alimentary canal go to line the salivary, pancreatic, and biliary ducts, and the gall-bladder.

(2) **Genito-urinary.** — The genito-urinary mucous membrane lines the inside of the bladder, and the whole urinary tract from the interior of the kidneys to the meatus urinarius, or orifice of the urethra; in the female it also lines the vagina, uterus, and Fallopian (uterine) tubes. A study of Figs. 98 and 99 will make this plain.

Structure. — A mucous membrane is composed of four layers of tissue which occur in the following order: —

(1) Epithelium.
(2) Basement membrane.
(3) Corium.
(4) Muscularis mucosæ.

(1) The *epithelium* is the most constant part of a mucous membrane, being continued over certain regions to which the other parts of the membrane

[1] Named after Eustachius, a famous anatomist.

cannot be traced. It may be scaly and stratified, as in the throat; columnar, as in the intestine; or ciliated, as in the respiratory tract.

(2) The *basement membrane* consists of a layer of flattened cells, and is really part of the corium.

(3) The *corium* of a mucous membrane is composed of either areolar or lymphoid connective tissue. It is generally much thicker than in serous or synovial membranes, and varies much in structure in different parts.

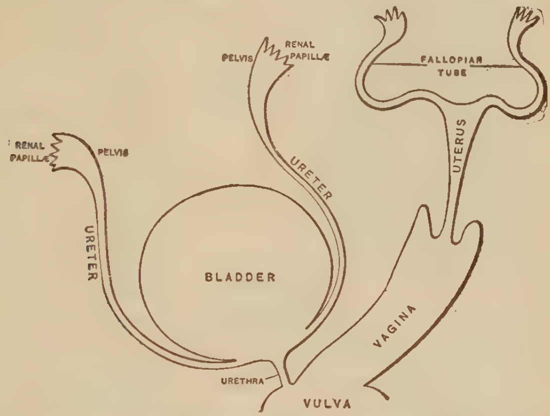


FIG. 98. — DIAGRAM OF THE FEMALE GENITO-URINARY MUCOUS MEMBRANE, SHOWING CONTINUITY OF ALL ITS PARTS. (Gerrish.)

(4) The *muscularis mucosæ* consists of a thin layer of muscular tissue.

The mucous membranes are attached to the parts beneath them by areolar tissue, here named *submucous*. This differs greatly in quantity as well as in consistency in different parts. The connection is in some cases close and firm, as in the cavity of the nose. In other instances, especially in cavities subject to frequent variations in capacity, like the œsophagus and the stomach, it is lax; and when the cavity is narrowed by contraction of its outer coats, the mucous membrane is thrown into folds, or *rugæ*, which disappear again when the cavity is distended. In certain parts the mucous membrane forms permanent folds that cannot be effaced, and these project conspicuously into the cavity which it lines. The best-marked example of these folds is seen in the small intestine, where they are called *valvulæ conniventes* [1] (circular folds),

[1] See page 285.

which are doubtless provided for increasing the amount of absorbing surface for the products of digestion. In some locations the free surface of mucous membrane contains minute glands, or is covered with papillæ, villi, or cilia.

Papillæ. — The papillæ are best seen on the tongue; they are small processes of the corium, mostly of a conical shape, containing blood-vessels and nerves, and covered with epithelium.

Villi. — The villi are most fully developed on the mucous coat of the small intestine. They are little projections of the mucous membrane, covered with epithelium, containing blood-vessels and lacteals, and are favorably arranged for absorbing nutritive matters from the intestines.

Cilia. — For description of cilia see page 29.

Function of mucous membranes. — The function of mucous membranes is (1) protection, (2) support of blood-vessels and lymphatics, (3) to furnish a large amount of surface for absorption.

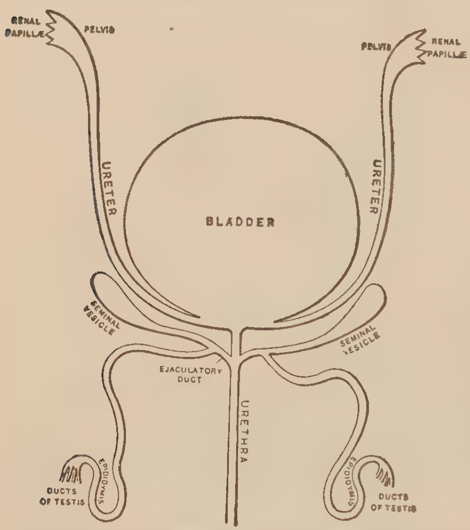


Fig. 99. — Diagram of the Male Genito-urinary Mucous Membrane Showing Continuity of All its Parts. (Gerrish.)

(1) It protects by forming a lining or inside skin for all the passages that communicate with the exterior. These passages are subject to the contact of foreign substances, which are introduced into the body; and waste materials, which are expelled from the body. The mucus which it secretes is a thicker and more sticky fluid than either serum or synovia, and by coating the surface lessens the possibility of irritation from food, waste materials, or secreted substances. The cilia of the respiratory tract also assist in the function of protection. They keep up an incessant motion, and thus carry mucus toward the outlet of these passages. Dust and foreign materials usually become entangled in the mucus and are forced out with it.

(2) The redness of mucous membranes is due to their abundant supply of blood. The small blood-vessels which convey blood to the mucous membranes divide in the submucous tissue, and send smaller branches into the corium, where they form a network of capillaries just under the basement membrane. The lymphatics also form networks in the corium, and communicate with larger vessels in the submucous tissue below.

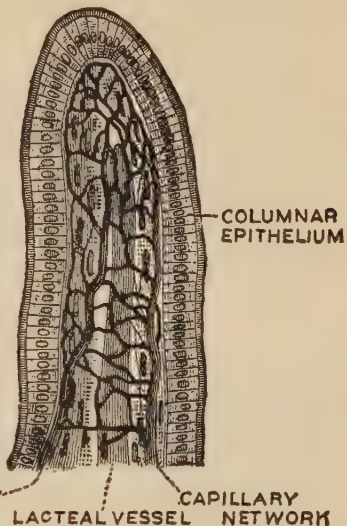


FIG. 100. — AN INTESTINAL VILLUS. (Highly magnified.)

(3) The modifications of mucous membrane, such as the valvulæ conniventes,[1] and villi, are largely for the purpose of increasing the surface for absorption, and also to enable it to carry more blood-vessels and lymphatics.

CUTANEOUS MEMBRANE

By this term is indicated the membrane which covers the body and is commonly spoken of as skin. It is a complex structure, and has several functions in addition to serving as a protective covering for the deeper tissues lying beneath it. It will be more fully considered in Chapter XVIII.

GLANDS

A gland is a secreting organ, or an organ which abstracts certain materials from the blood and makes of them a new substance.

The simplest form of a gland may consist of just one cell, such as the goblet cells,[2] or may be a mere depression on the surface of a membrane, or may consist of a vast number of secreting recesses. The liver and pancreas are examples of the latter. No matter

[1] See Fig. 168. [2] See page 274.

what the size or shape may be, all glands have three essential characteristics: (1) epithelial cells which are the active secreting agents, (2) a liberal blood supply from which the material for the secretion is drawn, (3) they are under the direct control of the nervous system and secretion is their response to stimulation, just as contraction is the response of a muscle. The usual arrangement is

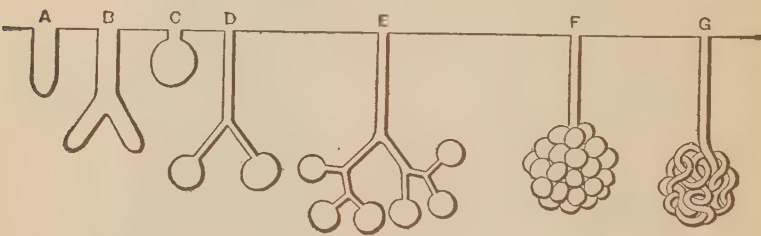


FIG. 101. — DIAGRAM SHOWING DEVELOPMENT OF GLANDS: *A*, a mere dimple in the surface or a simple tubular gland; *B*, enlargement by division or a branched tubular gland; *C*, enlargement by dilatation or a saccular gland; *D*, a combination of *B* and *C* or a branched saccular gland; *E*, a compound saccular or a racemose gland; *F*, development of method of *E*; *G*, a single tube intricately coiled or a convoluted tubular gland.

for the cells to cover the free surface of a basement membrane, a dense network of capillaries to be spread upon its under surface, and nerve fibrils to form a network in contact with the cells. In order to economize space and to provide a more extensive secreting surface, the membrane is generally increased by dipping down and forming variously shaped recesses. (See Fig. 101.)

Classification. — The secreting glands are of three kinds: —

1. Simple.
2. Compound.
3. Ductless.

1. **Simple glands.** — The simple glands are generally tubular or saccular cavities, which open upon the surface by a single duct. Sometimes the tube is so long that it coils upon itself, as in the sweat glands of the skin.

2. **Compound glands.** — In the compound glands the cavities are subdivided into smaller tubular or saccular cavities, opening by small ducts into the main duct, which pours the secretion upon the surface. If composed of many tubes, either straight or convoluted, they are called compound tubular glands; if composed of groups of small sacs, they are called racemose glands.

3. **Ductless glands.** — This term is applied to a collection of glandular structures that possess no ducts. Whatever secretion or excretion they produce is discharged into the blood, either directly or indirectly by way of the lymphatics.

SECRETION

A new substance, the product of a gland, elaborated from the blood by cell action, and intended for use in the body, is called a secretion.

For purposes of study we may divide the secretions into two groups: —

(1) External secretions.
(2) Internal secretions.

External secretions. — This term is used to designate those secretions of glandular tissues which are carried to their destination by a duct. All of the digestive fluids — saliva, gastric fluid, pancreatic fluid, bile, and intestinal fluid — are examples of external secretions, because they are carried off from the respective glands in which they are formed by means of ducts.

Function. — The function of the external secretions is dealt with in connection with the organs which produce them.

Internal secretions. — This term is used to designate those secretions of glandular tissues which are *not* carried off to the exterior by a duct, but instead are discharged into the blood or lymph. The conception is that probably all the ductless glands form secretions which are called internal secretions. It has also been shown that not only the ductless glands, but some at least of the typical glands provided with ducts, may give rise to internal secretions. For example, the pancreas forms the pancreatic fluid and discharges it by means of a duct into the small intestine. In addition, it is believed that the pancreas forms an internal secretion which passes into the blood.

Function. — The quick adaptive reactions by which emergencies are met and by which the various bodily activities are coördinated, are functions of the nervous system, but the internal secretions have a great deal to do with internal adjustments. They contain chemical substances called *hormones*, which are carried from place to place by the blood. A hormone is a substance produced in a

definite locality but having its effect elsewhere, perhaps at a great distance.[1]

Excretion. — An excretion is a secretion, except that the excretion is generally formed to be thrown out of the body, whereas the secretion is intended for use in the body. It therefore follows that all excretions are first secretions, and some substances are made use of before they are eliminated. For instance, bile serves several purposes before it is eliminated, so that it is first a secretion and then an excretion. Urine, on the other hand, is a secretion, but is formed only to be eliminated.

SUMMARY

MEMBRANES
- **Definition**
  - Any thin expansion of tissue.
  - An enveloping or lining tissue.
- **Varieties**
  1. Serous membranes.
  2. Synovial membranes.
  3. Mucous membranes.
  4. Cutaneous membranes.

SEROUS MEMBRANES
- **Consist of**
  1. Endothelium — a single layer of flat cells.
  2. Corium — a thin layer of fibrous tissue.
- **Found** — lining closed cavities or passages that do *not* communicate with the exterior. They are moistened by *serum*.
- **Three Classes**
  - Serous membranes proper
    - Pleuræ — cover the lungs and line the chest.
    - Pericardium — covers the heart and lines the outer fibrous pericardium.
    - Peritoneum — covers the abdominal and the top of some of the pelvic organs, lines the abdominal cavity.
  - Lining membrane of the vascular system
    - Heart.
    - Blood-vessels.
    - Lymphatics.
  - Lining membrane of certain cavities
    - Back of eye — capsule of Tenon.
    - Lining membrane of the cavity of the central nervous system.

[1] See *Secretin*, page 322.

SEROUS MEMBRANES

- **Function** — Protection
  - 1. Furnishes a cover or lining
    - Viscera.
    - Vascular system.
    - Certain cavities.
  - 2. Furnishes a secretion — serum — which acts as a lubricant.

SYNOVIAL MEMBRANES

- **Consist of**
  - 1. Imperfect layer of irregularly shaped cells.
  - 2. Layer of fibrous tissue.
- **Three Classes**
  - Articular synovial membranes — Surround cavities of movable joints.
  - Vaginal synovial membranes — Form sheaths for tendons.
  - Bursal synovial membranes — Sacs interposed between two surfaces which move upon each other.
- **Function** — Protection
  - Furnishes a cover or lining
    - Joints.
    - Tendons.
    - Sacs between muscles and bones.
  - Furnishes a secretion — synovia — which acts as a lubricant.

MUCOUS MEMBRANES

- **Found** — Lining passages that communicate with the exterior and are protected by *mucus*.
- **Two Divisions**
  - Gastropulmonary
    - Alimentary canal.
    - Air-passages.
    - Cavities communicating with both alimentary canal and air-passages.
  - Genito-urinary
    - Urinary tract.
    - Generative organs.
- **Consist of**
  - 1. Epithelium
    - Stratified.
    - Columnar.
    - Ciliated.
  - 2. Basement membrane, a layer of flat cells.
  - 3. Corium
    - Areolar tissue, or
    - Lymphoid tissue.
  - 4. Muscularis mucosæ — thin layer of muscular tissue.

MUCOUS MEMBRANES

- **Modifications**
  - Rugæ — temporary folds
    - Œsophagus.
    - Stomach.
  - Valvulæ conniventes — permanent folds of mucous membrane found in small intestine.
  - Papillæ — conical processes of mucous membrane best seen on tongue. Contain blood-vessels and nerves.
  - Villi — tiny thread-like projections of the mucous membrane of small intestine.
  - Cilia — hair-like processes.
- **Function**
  - Protection
    - Inside skin.
    - Secretion of mucus.
    - Action of cilia.
  - Support — for network of blood-vessels.
  - Absorption — Various modifications increase the surface.

GLANDS

- **Definition** — Glands are organs that form secretions.
- **Structure**
  - A single cell, or many cells arranged in various ways.
  - Essentials
    - Epithelial cells.
    - A liberal blood-supply.
    - Intimate connection with nervous system.
- **Classification**
  1. **Simple** — *one* duct.
  2. **Compound** — *many* ducts.
  3. **Ductless** — *no* duct.

SECRETIONS

- **Definition** — Secretions are substances elaborated from the blood by the glands. They are intended to perform some office in the body.
- **Classification**
  - *External secretions* — are substances formed by the simple and compound glands and discharged by means of a duct.
  - *Internal* secretions — are substances formed by any kind of gland and discharged into the blood or lymph.
- **Function**
  - External secretions — studied later.
  - Internal secretions
    - Essential to many internal adjustments.
    - Stimulate by means of hormones.
- **Excretion** — A secretion which is eliminated.

TABLE OF SECRETIONS AND EXCRETIONS

SECRETION	SECRETING ORGANS	REACTION	MAIN PURPOSE
Mucus	Mucous cells of mucous membrane	Alkaline	Lubricant and diluent.
Serum	Serous membranes	Alkaline	Lubricant and diluent.
Tears	Lacrimal glands	Alkaline	To moisten the conjunctiva.
Saliva	Salivary glands	Alkaline	To moisten food and begin the digestion of carbohydrates.
Gastric fluid	Stomach	Acid	To begin the digestion of proteins.
Pancreatic fluid	Pancreas	Alkaline	To digest proteins, fats, and carbohydrates.
Succus entericus	Intestines	Alkaline	To stimulate the secretion of pancreatic fluid, also digest proteins, fats, and carbohydrates.
Bile	Liver	Alkaline	Part of the bile is used in digestion and reabsorbed. Part is a true excretion (bile pigments).
Milk	Mammary glands	Alkaline	Food.
Sebum	Sebaceous glands of the skin	Alkaline	To lubricate the skin.
Sweat	Sweat-glands of skin	Alkaline	Helps to regulate body temperature. Eliminates water and carbon dioxide.
Vaginal	Vagina	Acid	Lubricant, moistens and protects.
Urine	Kidneys	Acid	Eliminates water and urea.

CHAPTER IX

VASCULAR SYSTEM: THE BLOOD; THE CLOTTING OF BLOOD; LYMPH

It is helpful to recall that the body consists of an enormous number of individual cells, and that each cell must be supplied with materials to enable it to carry on its activities, and at the same time it must have the waste materials that are the result of its activities removed. Many cells are far from the source of supplies and the organs of elimination; hence the need of a medium to distribute supplies and collect waste, and the need of a system so that the distribution will be orderly and systematic. These two needs are met by the *vascular system*, the divisions of which may be outlined as follows: —

Vascular System	Circulating fluids	Blood.
		Lymph.
	Systems	Blood vascular.
		Lymph vascular.

THE BLOOD

Characteristics. — The most striking external feature of the blood is its well-known color, which is blood red, approaching to scarlet in the arteries, but of a dark red or crimson tint in the veins.

It is a somewhat sticky liquid, a little heavier than water; its specific gravity is about 1.055. It has a peculiar odor, a saltish taste, a slightly alkaline reaction when tested with litmus, and a temperature of about 100° F. (37.8° C.).

Quantity of blood. — The quantity of blood contained in the body of an adult is estimated to be about $\frac{1}{20}$ of the body weight. This proportion was formerly said to be about $\frac{1}{13}$, but later experiments seem to place the figure at $\frac{1}{20}$. This, in an individual weighing 160 pounds (80 kilos), would weigh about 8 pounds (4 kilos), or measure 4 quarts (4 litres).

Functions of the blood. — Blood is commonly spoken of as the nutritive fluid of the body. This is correct, but it is more than a nutritive fluid, as will be seen from the following list of its functions: —

(1) It serves as a medium for the interchange of gases, *e.g.*, carries oxygen to the cells and carbon dioxide from the cells.

(2) It serves as a medium for the interchange of nutritive and waste materials. It carries food to the cells and waste materials from the cells.

(3) It serves as a medium for the transmission of internal secretions. The presence of these secretions controls the chemical activities of cells.

(4) It aids in equalizing the temperature of the body. Blood passing through a tissue which is undergoing lively metabolism will have a higher temperature when it leaves than it had when it entered. This extra temperature will be lost in passing through a tissue that is not so active. In this way an average temperature is maintained.

(5) It aids in protecting the body from toxic substances.

Composition of the blood. — Seen with the naked eye, the blood appears opaque and homogeneous; but when examined with a microscope it is seen to consist of minute, solid particles called cells or *corpuscles*, floating in a transparent, slightly yellowish fluid called *plasma*.

Blood	**Cells or Corpuscles**	Red or erythrocytes.
		White or leucocytes.
		Blood-plates.
	Plasma	

Red cells. — The red cells are usually described as being circular biconcave discs, with rounded edges. The average size is $\frac{1}{3200}$ of an inch (0.008 mm.) in diameter. Because of their extremely small size, the red cells do not appear red when viewed singly with a microscope, but merely of a yellowish red tinge, or yellowish green in venous blood. It is only when great numbers of them are gathered together that a distinctly red color is produced.

Authorities differ regarding the structure of the red cells. Some describe them as consisting of a colorless, filmy, elastic framework infiltrated in all parts by a red coloring matter termed hæmoglobin.

Others describe them as consisting of a colorless elastic envelope enclosing a solution of hæmoglobin. In either case it is correct to consider them as packets of hæmoglobin moving passively at the mercy of the blood current. They have no nuclei, are soft, flexible, and elastic, so that they readily squeeze through apertures and passages narrower than their own diameters, and immediately resume their proper shape.

Hæmoglobin. — Hæmoglobin is a substance which is formed of an iron salt and a protein. In the presence of oxygen it has the power to combine with it to form an unstable compound called oxyhæmoglobin, and in an environment where oxygen is scarce, it gives up this oxygen, and is then known as reduced hæmoglobin.

Hemolysis or "Laking." — Under certain circumstances hæmoglobin may pass out of the red cells into the surrounding fluid. This process is known as hemolysis or "laking" and a few of the ways in which it may be brought about are (1) by adding water to the blood, (2) by adding to it the blood of certain other animals,[1] and (3) by adding to it various toxins such as snake venom or certain products of bacterial activity.

Number of red cells. — The average number of red cells in a cubic millimetre of healthy blood is given as 5,000,000 for men, and 4,500,000 for women. Pathological conditions may cause a marked diminution in number, and differences have been observed even in health. The number varies with altitude; temperature; the constitution, nutrition, and manner of life; with age, being greatest in the fœtus and new-born child; with the time of day, showing a diminution after meals; in the female menstruation is accompanied by an increase and pregnancy by a decrease. The condition known as anemia may be due to a diminished number of red cells which means a diminished supply of oxygen, and a consequent interference with the processes of metabolism.

Function of the red cells. — The red cells, or erythrocytes, by virtue of the hæmoglobin which they contain, are emphatically *oxygen carriers*. Exposed to the air in the lungs the hæmoglobin becomes fully charged with detachable oxygen and is known as oxyhæmoglobin. The red cells carry this oxyhæmoglobin to

[1] Before transfusing blood from one human being to another, the blood of the donor is always tested in several ways. The purpose of one test is to make sure that it will not hemolyze the red cells of the recipient.

the tissues, where it gives up the loosely engaged oxygen. It is then known as reduced hæmoglobin and is ready to be carried to the lungs for a fresh supply. The color of the blood is dependent upon the combination of the hæmoglobin with oxygen; when the hæmoglobin has its full complement of oxygen, the blood has a bright red hue; when the amount is decreased, it changes to a dark crimson hue. The scarlet blood is usually found in the arteries, and is called arterial; the dark crimson in the veins, and is called venous blood.

Life cycle of the red cells. — The red cells like all the cells of the body have a definite term of existence. There is every reason to believe that this term of existence is very short, possibly not more than a few days. They originate in the red marrow of the bones. Before entering the blood stream they lose their nuclei, and this of itself suggests that they do not live a great while in the circulation. It has been suggested that their destruction takes place in the liver, spleen, or lymph nodes.[1]

White cells. — The white cells are typical cells containing a nucleus, sometimes even two or three nuclei. They are variable in size, but are somewhat larger than the red cells.

Number of white cells. — The average number of white cells in a cubic millimetre of healthy blood is from 5000 to 7000. A marked increase in number is designated as *leucocytosis,* a marked decrease as *leucopenia.* Leucocytosis[2] occurs under normal conditions, such as digestion, exercise, or cold baths. It also occurs under abnormal conditions, and a knowledge of the variations under pathological conditions is an important aid in diagnosis.

[1] Some authors give the weight of man as 70 K., and as 1 K. equals 2.28 lb. or 1000 gm., this reduced to grams would give 70,000 gm. as the weight of man. We are taught that the blood in the body equals $\frac{1}{20}$ of the body weight. $\frac{1}{20}$ of 70,000 gm. is 3500 gm. In every 100 gm. of blood there are 14 gm. of hematin so that 3500 gm. of blood would contain 3500 divided by 100, multiplied by 14, which equals 490 gm. This means that the body contains 490 gm. of hematin. The destruction products of 48 gm. of hematin are eliminated by the liver daily. Hence, it would take as many days to eliminate 490 gm. as 48 gm. is contained in it. This equals ten days plus, and gives us the approximate life of a red blood cell. According to some authors, the daily loss of pigment is much less, hence the life of the red cells would be much longer.

[2] Leucocytosis is found in practically all infectious processes except typhoid and tuberculosis. A leucocytosis is demonstrated by a "blood count," *i.e.*, counting the white blood cells in a given volume of a known dilution of blood, using special pipettes and ruled slides, under the microscope. Any considerable increase, *i.e.*, over 8000, is evidence of a leucocytosis.

Varieties of white cells. — At least five varieties have been studied and described. They are classified under two main groups: —

(1) Lymphocytes.
(2) Leucocytes.

The most marked difference is in the nuclei and in the amount of amœboid movement exhibited.

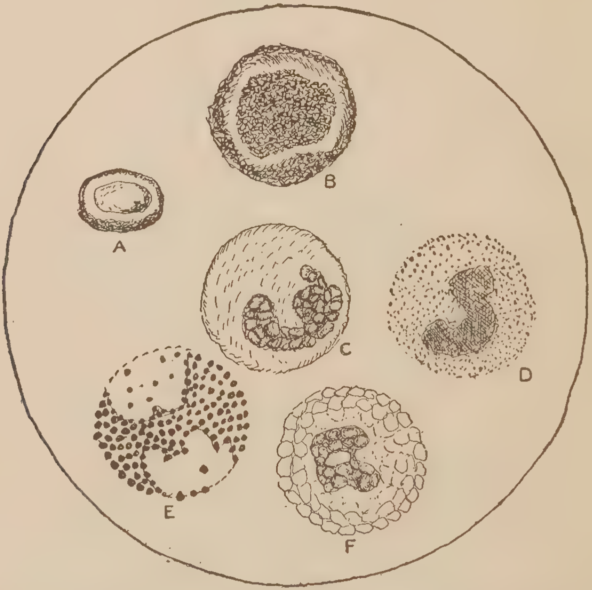


FIG. 102. — VARIETIES OF WHITE CELLS FOUND IN HUMAN BLOOD. When stained with blood stains various kinds of white cells can be distinguished. Five varieties are shown above. *A*, lymphocyte; *B*, *C*, mononuclear leucocytes; *D*, polynuclear leucocyte; *E*, eosinophile leucocyte; *F*, mast cell.

Each of these groups may be subdivided into two or more subgroups, and some authorities hold that each variety has some special function, but this has not been proven.

Amœboid movements of white cells. — One distinctive property of white cells is their power of making amœboid movements, which enables them to change their form and escape through the walls of the blood capillaries into the surrounding tissues. This property has earned for them the title of *wandering cells* and the process is spoken of as migration. It occurs under normal conditions, but is vastly accelerated under pathological conditions.

Function of the white cells. — Many functions are ascribed to the white cells, and many theories are advanced in support of

these functions. A few of the most important are (1) they act as protective agents, (2) they aid in the absorption of digested fats and proteins from the intestines,[1] (3) they assist in clotting of the blood.[2] Their function of protection is very important and it has been suggested that it may be accomplished in two ways: —

(*a*) By contributing to the formation of antibodies;[3] (*b*) by virtue of their amœboid movement they can project irregular processes which are very sticky, so that the bacteria stick to them, and are ingested by them. This process is called *phagocytosis* and has earned for them the name of *phagocytes*. According to some authorities this property depends upon the presence in the plasma of a certain class of antibodies called *opsonins*[4] which in some way prepares bacteria for ingestion by the leucocytes.

Inflammation. — When any of the tissues become inflamed either as the result of injury or infection, the first effect is irritation, followed by an increased supply of blood to the part. If the irritation continues or is severe, the flow of blood begins to slacken, and a condition of stasis or engorgement results. The white cells become particularly active and migrate into the infected tissues in large numbers. Some of the blood plasma exudes, and a small number of red cells are forced through the capillary walls.[5] This general condition is described as inflammation, and the symptoms of pain, heat, redness, and swelling are due, (1) to the increased supply of blood, (2) to the engorgement of the blood-vessels, and (3) to the collection of fluid in the tissues, which is spoken of as inflammatory exudate. Under these conditions a death struggle between the leucocytes and bacteria takes place. If the leucocytes are victorious, they not only kill the bacteria but remove every vestige of the struggle, and find their way back to the blood. If the bacteria are victorious, and suppuration ensues, the leucocytes become pus cells. Also, in the case of a wound, the leucocytes, by virtue of their amœboid movements, escape from the blood-vessels, accumulate in the region of the wound, and act as barriers against infection.

[1] See page 325. [2] See page 163. [3] See page 162.

[4] From opso'no, I prepare food for.

[5] This passive ability of red corpuscles to pass through the capillary walls is called *diapedesis*.

Life cycle of the white cells. — The white cells like all other cells have a definite term of existence. We do not know the length of this term, or where they are destroyed, except that large numbers are lost in the battle waged against bacteria, others by hemorrhage, and others may be converted into granulation tissue. These lost leucocytes are replaced by new leucocytes which result from the division of former leucocytes. This division usually takes place in the lymph nodes and the spleen.

Differences between white and red cells. —

(1) White cells are larger than red cells, but normally are present in smaller numbers.

(2) They have no pigment or hæmoglobin, hence are colorless.

(3) On account of the property of amœboid movement their shape varies.

(4) They always have a nucleus, sometimes two or three nuclei.

(5) There are five varieties that differ in microscopical structure and possibly in function.

(6) During circulation they keep close to and even seem to adhere to the walls of the vessels, while the red cells keep in the middle of the stream.

(7) By virtue of their amœboid movement they escape through the walls of the capillaries and are found in the tissue spaces. They are also found in lymph, chyle, and pus.

(8) The functions of the white cells are quite different from the function of the red cells.

Blood-plates. — They are disc-shaped bodies, which vary in size but are always smaller than the red cells. Their origin, fate, and function are still open questions. It is not decided whether they are to be considered as independent cells or as fragments of disintegrated cells. There is considerable evidence to show that they take part in the process of clotting. (See page 163.)

Plasma. — The plasma of the blood is of a clear, slightly yellowish color. It is a very complex fluid and contains a great variety of substances as might be inferred from its double relation to the cells, serving as a source of nutrition and as a means of removing the waste products that result from their functional activity. It consists of water holding in solution or suspension: —

Proteins	Fibrinogen. Paraglobulin or serum-globulin. Serum-albumin.		
Extractives	Sugars. Fats.		
	Urea Uric acid Hippuric acid Creatin Creatinin	Represent waste products.	
Inorganic Salts	Chlorides Sulphates Phosphates Carbonates	of	Sodium. Calcium. Magnesium.
Gases	Oxygen. Nitrogen. Carbon dioxide.		
Internal Secretions			
Enzymes			
Special Substances [1]	Antithrombin. Prothrombin. Epinephrin. Antigens and Antibodies.		

Proteins of the blood-plasma. — Three proteins are usually described as existing in the plasma of circulating blood, *i.e.*, fibrinogen, paraglobulin, and serum-albumin. The first two of these proteins belong to the group of globulins and hence have many properties in common. Serum-albumin belongs to the group of albumins [2] of which white of egg constitutes another member.

Many experiments seem to indicate that fibrinogen may be formed in the liver. When blood is shed fibrinogen is changed to an insoluble protein known as fibrin.[3] The significance of paraglobulin and serum-albumin is obscure. Not long ago they were thought to be formed continually in the cells lining the intestine, and consumed as food by the tissues, but this does not seem so probable since the presence of amino-acids [4] in the blood has been shown. They are now looked upon as

[1] This list is by no means complete. For more detailed analysis the student is referred to the standard books on Physiology and Physiological Chemistry.

[2] Albumins and globulins give the same general tests; they are both coagulated by heat, and the chief difference is in their solubilities.

[3] See page 163. [4] See page 308.

a rather stable and permanent mass, little subject to depletion and hence requiring little renewal.

Extractives. — Extractives are substances other than proteins that may be extracted from dried blood by special methods.

Sugar in the form of glucose is present under normal conditions in the amount of 0.1 to 0.15 per cent. A temporary increase in the amount of sugar may follow the ingestion of a large quantity.

Fat is found in the plasma in about the same proportion as sugar. It is much more subject to variation, rising notably after a meal in which there was much fat.

Waste products found in the plasma represent the end products resulting from the oxidation of our food. Due to the efficiency of the kidneys, they occur in very small quantities.

Salts. — The salts found in the blood are derived from the food and from the chemical reactions going on in the body. The most abundant is sodium chloride.

Gases. — Oxygen, nitrogen, and carbon dioxide gas are found in the blood. Carbon dioxide is the result of oxidation in the tissues, and is found in both arterial and venous blood, but the quantity is greater in venous blood.

Internal secretions. — The blood serves as a medium to carry internal secretions. (See page 149.)

Enzymes. — See page 311.

Special substances. — Antithrombin and prothrombin are considered in connection with the clotting of blood.

Epinephrin. — It is generally believed that the blood receives a constant supply of epinephrin from the adrenal glands. (See page 345.)

Antigens and Antibodies. — The term antigen is applied to substances which stimulate the formation of antibodies. The term *antibodies* includes all defensive substances found in the blood, *e.g.*, agglutinins, opsonins, antitoxins, immune bodies, etc. When the body is invaded by pathogenic bacteria, the toxic substances produced by these organisms (antigens) stimulate the tissues to form specific antitoxins (antibodies) which are capable of neutralizing the action of the bacterial toxins.

THE CLOTTING OF BLOOD

Blood when drawn from the blood-vessels of a living body is perfectly fluid. In a short time it becomes viscid, and this viscidity increases rapidly until the whole mass of blood becomes a complete jelly. If the blood in this jelly stage be left untouched in a glass vessel, a few drops of an almost colorless fluid soon make their appearance on the surface of the jelly. Increasing in number and running together, the drops after a while form a superficial layer of pale straw-colored fluid. Later on, similar layers of the same fluid are seen at the sides, and finally at the bottom of the jelly, which, shrunk to a smaller size and of firmer consistency, now form a *clot*, floating in a fluid which is called *serum*. If a portion of the clot is examined under the microscope, it is seen to consist of a network of fine fibrils, in the meshes of which are entangled the red and some of the white cells of the blood. The fibrils are composed of fibrin, which is essential to the formation of a clot. The formation of insoluble fibrin from soluble fibrinogen is an instance of enzyme action and is comparable to the clotting of milk under the influence of rennin. The enzyme which causes the fibrin to form is called thrombin, and exists in the blood in an inactive form called prothrombin. Prothrombin may be converted to active thrombin by the action of calcium, but in circulating blood this is prevented by another enzyme called antithrombin. This antithrombin must be neutralized to permit the calcium to react with prothrombin to form thrombin, which in turn reacts with the fibrinogen to form fibrin. One theory is that this neutralizing or thromboplastic[1] substance is furnished by the blood-plates, leu-

FIG. 103. — BOWL OF RECENTLY CLOTTED BLOOD, SHOWING THE WHOLE MASS UNIFORMLY SOLIDIFIED. (Dalton.)

FIG. 104. — BOWL OF CLOTTED BLOOD AFTER TWELVE HOURS, SHOWING THE CLOT CONTRACTED AND FLOATING IN THE FLUID SERUM. (Dalton.)

[1] Various preparations of thromboplastic material are obtainable, and are in use to check hemorrhage. Some are applied externally to a bleeding surface such

cocytes, and cells of the tissues over which the blood flows when it escapes from the blood-vessels.

This may be represented in diagrammatic form as follows: —

Cellular elements of blood and tissues → thromboplastic substance.
Thromboplastic substance neutralizes antithrombin.
Prothrombin + calcium → thrombin.
Thrombin + fibrinogen = clot.

Value of clotting. — This property is of very great importance in the arrest of hemorrhage. The clot formed closes the openings of wounded vessels, and the procedures used to check hemorrhage are directed toward hastening the formation of a clot, and stimulating the blood-vessels to contract so that a smaller-sized clot will be sufficient.

The clotting power of the blood differs in different individuals and in rare cases is so slight that the most trivial operation involving hemorrhage is attended with great danger. This condition is known as hemorrhagic diathesis or hemophilia.

Conditions affecting clotting. — Clotting is hastened by: —

(1) A relatively high temperature, *e.g.*, the use of hot towels to check bleeding from the stump of an amputated limb; the use of hot douches to check postpartum hemorrhage.

(2) Contact with any foreign substance, or rough surface such as gauze.

(3) Injury to the walls of the blood-vessels.

(4) Rest.

If blood is contained in a dish agitation hastens the process of clotting, because like the first three conditions it favors the formation of thromboplastic substance.

Clotting is hindered by: —

(1) A very low temperature. Cold hinders the formation of a clot but is often used to check hemorrhage, because it stimulates the blood-vessels to contract.

(2) Contact with the lining of the heart and blood-vessels.

(3) The addition of strong acids or alkalies, neutral salts, oil or other viscid substances, certain organic ferments, or a large quantity of water.

(4) Absence of calcium salts.

as is left after an operation for removal of tonsils; or injected into the tissues, and one, *i.e.*, cephalin-protein, is introduced directly into the blood-vessels.

antikinase = has to be present
thrombin calc. com.

(5) Absence of fibrinogen.

(6) Removal of fibrin. If fresh blood, before it has time to clot, be whipped with a bundle of twigs, the fibrin will form on the twigs, and if the whipping of the blood be continued until after the fibrin has been deposited on the twigs, the blood left in the vessel will be found to have lost the power of clotting. Such blood is called **defibrinated**.

Why blood does not clot within the blood-vessels. — In accordance with the theory of clotting which we have considered, blood does not clot within the blood-vessels because of the presence of *antithrombin*.

Intravascular clotting. — It is well known that clots occasionally form within the blood-vessels. The most frequent causes are: —

(1) When the internal coat of a blood-vessel is injured, as for instance by a ligature, the endothelial cells are altered and may act as a foreign substance. If in addition there is a stasis of blood at this point, disintegration of the blood-plates and white cells may result in the formation of thrombin and a clot.

(2) Any foreign material, even air, that is introduced into the blood and not absorbed, may stimulate the formation of thrombin and a clot.

Thrombus and embolus. — A clot which forms inside a blood-vessel is called a thrombus. A thrombus may be broken up and disappear, but the danger is that it may be carried to some point in an important vessel where it acts as a wedge, blocks circulation, and may cause instant death. A thrombus that becomes dislodged from its place of formation is called an embolus.

Regeneration of the blood after hemorrhage. — A large portion of the total amount of blood in the body may be lost suddenly by hemorrhage without producing a fatal result. It is probable that a healthy individual may recover from the loss of as much as three per cent of the body weight, provided the lost blood is at once replaced by a solution having the same degree of concentration (*i.e.*, isotonic) and containing one or more of the important salts of the blood. Physiological saline solution, *i.e.*, sodium chloride 0.7 to 0.9 per cent, fulfills these conditions, and is usually introduced directly into a vein. This operation is called *intravenous infusion*, and the benefits derived from it are: —

(1) The heart-beat is increased, because it must make stronger contractions to propel the extra fluid.

(2) The volume of the circulating fluid is sufficiently increased to maintain normal conditions of pressure and velocity.

(3) The red cells are kept in rapid circulation and thus loss of oxygen to the tissues is prevented.

(4) The tissue cells are provided with water and thus protected from the bad effects that would follow the withdrawal of water.

Plasma is regenerated with some rapidity (probably within a few hours) but it may take days or even weeks before the number of red cells and the quantity of hæmoglobin is replaced.

LYMPH

Lymph is a colorless liquid found in the lymph-vessels and in all the tissue-spaces of the body. It is slightly alkaline, has a salty taste, and no odor. When examined with the microscope, it is seen to consist of a clear liquid with white cells floating in it. In composition it resembles the blood-plasma, as indicated in the following table: —

Blood	Lymph
Specific gravity about 1.055	Specific gravity about 1.015
Contains red cells	Does not contain red cells (normally)
Contains white cells	Contains white cells
Contains blood-plates	Does not contain blood-plates
A high content of proteins	A low content of proteins
A low content of waste products	A higher content of waste products
Normally — clots quickly and firmly	Clots slowly and does not form a firm clot

Sources of lymph. — By the action of physical and chemical processes, the details of which are not entirely understood, the plasma of the blood makes its way through the thin walls of the capillaries into such spaces as exist between the cells forming the tissues. Some physiologists claim that the combined action of the physical processes of filtration, diffusion and osmosis, is sufficient to account for the formation of lymph. Others claim that in addition it is necessary to assume an active secretory process on the

part of the endothelial cells composing the capillary walls. This plasma plus the leucocytes that have left the vessels by migration make up the lymph. Besides this the lymph that fills the lacteals of the intestinal villi absorbs some of the products of digestion, especially the fats.

The portion of the lymph that has absorbed the fats is milky in appearance, and is called *chyle*. The lymph, broadly speaking, is dilute blood-plasma minus its red cells. The chyle is lymph plus a very large quantity of minutely divided fat.

Functions of the lymph. — The lymph bathes all portions of the body not reached by the blood. It delivers to the cells the material each cell needs to maintain its functional activity, and picks up and returns to the blood the products of this activity, which products may be simple waste, or matters capable of being made use of by some other tissue. There is thus a continual interchange going on between the blood and the lymph. This interchange is effected by means of osmosis and dialysis.

Osmosis and dialysis. — The lymph becomes altered by the metabolic changes of the tissues which it bathes, and we have two different fluids, separated by the moist membrane which forms the walls of the blood-vessels, — the lymph in the tissues outside the walls of the capillaries and the blood inside the capillary walls. Some of the constituents of the lymph pass into the blood, while some of the constituents of the blood pass into the lymph, by the processes of osmosis and dialysis.[1]

In consequence of the different wants and wastes of different tissues at different times, both the lymph and blood must vary in composition in different parts of the body. But the loss and gain is so fairly balanced that the average composition is pretty constantly maintained.

The chyle, or lymph of digestion, absorbs nutrient materials (mostly fat) from the intestines and pours this food into the blood current, to be distributed to all parts of the body.

[1] See page 12.

SUMMARY

- **Vascular System**
  - **Circulating Fluids**
    - Blood.
    - Lymph.
  - **Systems**
    - Blood vascular.
    - Lymph vascular.
- **Blood . . .**
  - **Description**
    - Color
      - Bright red in arteries.
      - Dark red in veins.
    - Sticky fluid.
    - Specific gravity, about 1.055.
    - Alkaline reaction when tested with litmus.
    - Temperature, 100° F.
    - Peculiar odor. Salty taste.
    - $\frac{1}{20}$ of the body weight.
  - **Functions**
    - Serves as a medium for the interchange of gases.
    - Serves as a medium for the interchange of nutritive and waste materials.
    - Serves as a medium for the transmission of internal secretions.
    - Aids in equalizing the temperature of the body.
    - Aids in protecting the body from toxic substances.
  - **Composition**
    - Cells (minute, solid particles)
      - Red, or erythrocytes.
      - White, or leucocytes.
      - Blood-plates.
    - Plasma, transparent, slightly yellowish fluid.
      - Water, 90%.
      - Proteins.
      - Extractives.
      - Inorganic salts.
      - Gases.
      - Internal secretions.
      - Enzymes.
      - Special substances.
- **Red Cells**
  - **Description**
    - Biconcave discs $\frac{1}{3200}$ in. in diameter.
    - Packets of hæmoglobin
      - Iron salt.
      - Protein.
    - Have no nuclei.
    - Soft, flexible, and elastic.
  - **Number**
    - Cubic millimetre of blood
      - 5,000,000 for men.
      - 4,500,000 for women.
    - Number varies, even in health.
    - Pathological conditions may cause decrease.

- **Red Cells**
  - **Function**
    - Oxygen carriers.
    - Color due to oxygen in combination with hæmoglobin.
  - **Life Cycle**
    - Originate in red marrow of bones.
    - Lose their nuclei before being forced into the circulation, which suggests that their term of existence is short.
    - Disintegrate probably in
      - Liver.
      - Spleen.
      - Lymph nodes.

- **White Cells**
  - **Description**
    - Typical cells
      - Masses of protoplasm.
      - Nucleus (sometimes two or three nuclei).
      - No cell-wall.
      - Variable in size, but larger than red cells.
  - **Number**
    - Cubic millimetre of blood
      - 5000 to 7000.
      - Marked increase = leucocytosis.
      - Marked decrease = leucopenia.
  - **Varieties**
    1. Lymphocytes.
    2. Mononuclear leucocytes.
    3. Polynuclear leucocytes.
    4. Eosinophile leucocytes.
    5. Mast cells.
  - **Functions**
    1. Protective agents
       - (*a*) By contributing to the formation of antibodies.
       - (*b*) By process of phagocytosis.
    2. Aid in absorption of fats and proteins.
    3. Assist in clotting of blood.
  - **Life Cycle**
    - New leucocytes formed in lymph nodes and spleen.
    - Numbers lost in
      - (1) Battles against bacteria.
      - (2) Hemorrhage.
      - (3) Formation of granulation tissue.

- **Inflammation**
  - Irritation resulting from injury or infection.
  - Engorgement of blood-vessels.
  - Migration of white blood-cells.
  - Diapedesis of red blood-cells.
  - Exudation of plasma.
  - **Symptoms**
    - Pain.
    - Heat.
    - Redness.
    - Swelling.

- **Inflammation**
  - **Result**
    - (*a*) Resolution — White blood-cells eat up bacteria, clear up débris, and return to blood.
    - (*b*) Suppuration — Bacteria destroy white blood-cells and tissue cells, and form pus.
    - (*c*) Pus consists of
      - Plasma.
      - Red cells.
      - White cells.
      - Tissue cells.
      - Bacteria
        - dead.
        - living.
      - Toxins produced by bacteria.

- **Differences between white and red cells**
  1. Size and number.
  2. Color.
  3. Property of amœboid movement and shape.
  4. Nucleus or nuclei.
  5. Varieties.
  6. Location during circulation.
  7. Migration. Found in other fluids.
  8. Functions.

- **Blood-plates**
  - **Description**
    - Disc-shaped bodies, vary in size, always smaller than red cells.
    - Origin, fate, and function are open questions.
    - May assist in clotting of blood.

- **Plasma**
  - **Water**, 90%.
  - **Proteins**
    - Serum-albumin, Paraglobulin — Significance of these bodies is obscure.
    - Fibrinogen produces the fibrin of clotted blood.
  - **Extractives**
    - Sugar
      - Normally present, 0.1% to 0.15%.
      - May be increased after ingestion of large amount.
    - Fats
      - Derived from food.
      - Amount subject to wide variations.
    - Urea, Uric acid, Hippuric acid, Creatin, Creatinin — Represent waste products, result of oxidation of food. Normally present in small quantities.

- **Plasma**
  - **Inorganic Salts**
    - Chlorides, Sulphates, Phosphates, Carbonates of Sodium, Calcium, Magnesium
      - Derived from our food, and also result from chemical reactions in our bodies.
  - **Gases**
    - Oxygen.
    - Nitrogen.
    - Carbon dioxide. Found in both arterial and venous blood.
  - **Internal Secretions** — See page 149.
  - **Enzymes**
    - Substances produced by living cells which act by catalysis.
  - **Special Substances**
    - Antithrombin, Prothrombin — function in connection with clotting of blood.
    - Epinephrin — active principle of internal secretion of adrenal glands.
    - Antigens — substances which stimulate the tissues to form antibodies.
    - Antibodies — defensive substances found in the blood.
- **Clotting**
  - **Description**
    - Serum
      - Water.
      - Mineral salts.
      - White cells.
      - Albumin.
    - Clot
      - Fibrin formed from fibrinogen.
      - Cells, red and white.
    - Process
      - Cellular elements of blood and tissues → thromboplastic substance.
      - Thromboplastic substance neutralizes antithrombin.
      - Prothrombin + calcium → thrombin.
      - Thrombin + fibrinogen → clot.
  - **Value** . . Checks hemorrhage.
  - **Hemophilia** Condition of blood that lacks clotting power.
  - **Hastened by**
    - A temperature higher than that of body.
    - Contact with any rough surfaces.
    - Contact with foreign substances.
    - Injury to the walls of the vessels.
    - Rest.
  - **Hindered by**
    - A very low temperature.
    - Contact with lining of the heart and blood-vessels.

- **Clotting**
  - **Hindered by**
    - Addition of strong acids, alkalies, neutral salts, oils, certain ferments, water.
    - Absence of calcium salts.
    - Absence of fibrinogen.
    - Removal of fibrin. (Defibrinated blood.)
- **Intravascular Clotting**
  - **Theory to account for rare occurrence**
    - Circulating blood contains antithrombin.
  - **Causes**
    - Injury to internal coat of blood-vessels.
    - Any foreign material that will stimulate clotting.
  - **Thrombus**
    - Name given to clot which forms inside vessel.
  - **Embolus**
    - A thrombus that has become dislodged from place of formation.
- **Regeneration of blood after hemorrhage**
  - If immediate ill effects are counteracted by intravenous infusion, plasma is regenerated rapidly, red cells within a few days or weeks.
- **Intravenous Infusion**
  - **Definition**. Injection of physiological saline solution directly into vein.
  - **Benefits**
    1. Heart stimulant.
    2. Increases volume of circulating fluid.
    3. Red cells kept circulating, and oxygen supply kept up as far as possible.
    4. Tissue cells provided with water.
- **Lymph**
  - **Description**
    - Colorless liquid.
    - Alkaline reaction when tested with litmus.
    - Salty taste. No odor.
    - Consists of blood plasma plus leucocytes.
    - Specific gravity about 1.015.
    - Contains a low content of proteins.
    - Contains a high content of waste products.
    - Clots slowly, does not form a firm clot.
  - **Sources**
    - Physical processes of
      - Filtration.
      - Diffusion.
      - Osmosis.
    - Active secretory process on part of endothelial cells.
  - **Function**
    - Lymph acts as middleman between the blood and the tissues.
    - Carries nourishment *from* blood to tissues.
    - Carries waste from tissues to blood.
    - Dependent upon osmosis and dialysis.
  - **Chyle**. Lymph plus nutrient material, mostly fats.

CHAPTER X

THE BLOOD VASCULAR SYSTEM, AND THE LYMPH VASCULAR SYSTEM

BLOOD VASCULAR SYSTEM

THE blood is the internal medium on which the cells live. It is contained in branched tubes named blood-vessels. It is driven along these tubes by the action of the *heart,* which is a hollow muscular organ placed in the centre of the vascular system. One set of vessels — the *arteries* — conducts the blood out from the heart and distributes it to the different parts of the body, whilst other vessels — the *veins* — bring it back to the heart again. The blood from the arteries gets into the veins by passing through a network of fine tubes which connect the two, and which are named, on account of their small size, the *capillary* (*i.e.*, hair-like) vessels.

Blood Vascular System	Heart.
	Arteries — small arteries are named arterioles.
	Capillaries.
	Veins — small veins are named venules.

HEART

The heart is a hollow, muscular organ, situated in the thorax between the lungs, and above the central depression of the diaphragm. It is about the size of the closed fist, shaped like a blunt cone, and so suspended by the great vessels that the broader end or base is directed upward, backward, and to the right. The pointed end or apex points downward, forward, and to the left. As placed in the body, it has a very oblique position, and the right side is almost in front of the left. The impulse of the heart against the chest wall is felt in the space between the fifth and sixth ribs, a little below and to the inner side of the left nipple.

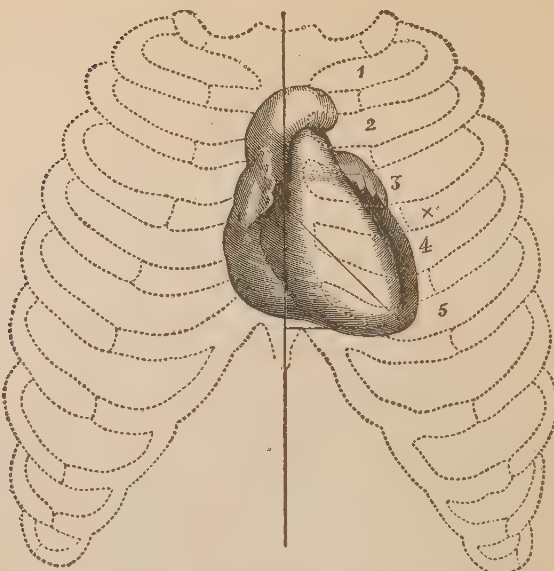


Fig. 105. — Heart *in situ* (Dalton, in Flint, "On the Heart"). 1, 2, 3, 4, 5, intercostal spaces; vertical line, median line; triangle, superficial cardiac region; × on the fourth rib, nipple.

Myocardium.—The main substance of the heart is composed of muscular tissue and is called *myocardium*. (See page 100.)

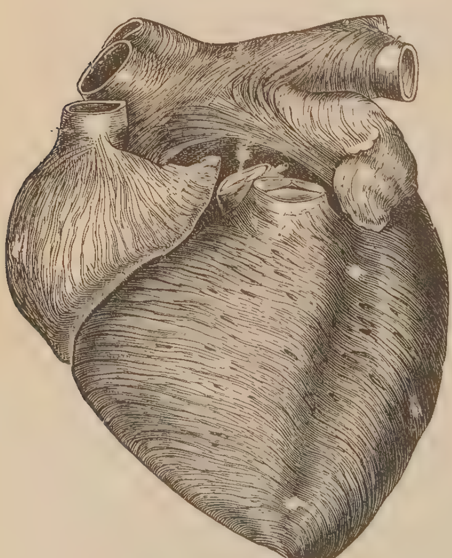


Fig. 106. — Anterior View of Heart, Dissected, after Long Boiling, to Show the Superficial Muscles. (Quain.)

The arrangement of the muscles is very intricate; they run transversely, longitudinally, obliquely, and in the apex take a spiral turn or twist. Between the muscles is a certain amount of reticular tissue, with numerous blood-vessels and lymphatics, and, in some parts, nerves and ganglia. There is also a considerable amount of fat, collected chiefly at the base of the heart, beneath the pericardium.

Pericardium. — The heart is covered by a membranous sac called the pericardium (around the heart). It consists of two parts: (1) an external fibrous portion, and (2) an internal serous portion.

(1) The **external fibrous** pericardium is composed of white fibrous tissue, and is attached by its upper surface to the large

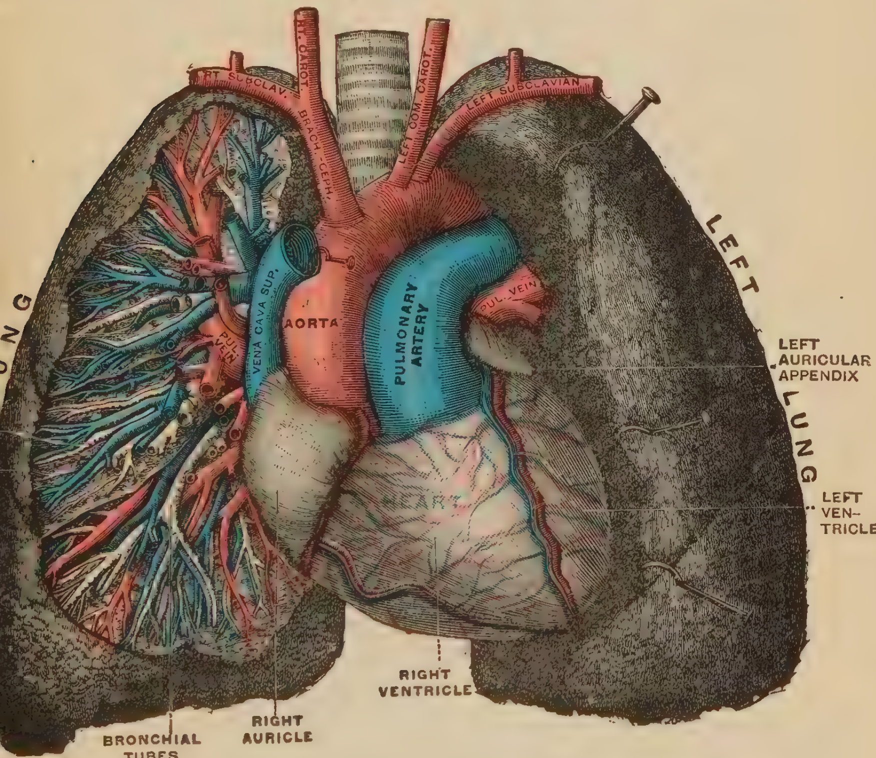


FIG. 107. — THE PULMONARY ARTERY AND AORTA. The front part of the right lung has been removed, and the pulmonary vessels and the bronchial tubes are thus exposed. Note the artery marked "brach.-ceph." It is also named the innominate. (See page 203.) (Gerrish.)

blood-vessels which emerge from the heart. It covers these vessels for about an inch and a half (3.8 cm.) and blends with their sheaths. The lower border is firmly adherent to the diaphragm, and the front surface is attached to the sternum by means of fibrous bands.

(2) The **internal or serous portion** of the pericardium is a completely closed sac; it envelops the heart and lines the fibrous

pericardium. The heart, however, is not within the cavity of the closed sac. (See Fig. 108.) That portion of the serous pericardium which lines and is closely adherent to the heart is called the visceral portion (*viscus*, organ); the remaining part of the serous pericardium, namely, that which lines the fibrous pericardium, is known as the parietal portion (*paries*, a wall). The cavity of the serous pericardium contains a small quantity of serous liquid. Its opposed surfaces are lined by endothelium and are very smooth and polished.

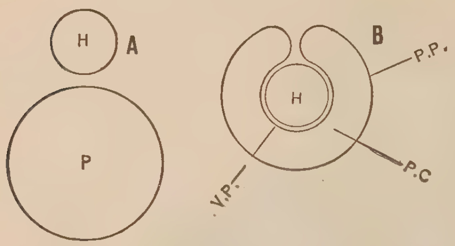


Fig. 108. — Diagram of the Heart and Serous Pericardium. *A* shows heart and pericardium lying separately. *B* shows the pericardium invaginated by the heart. *V. P.* shows visceral layer that clings close to the heart muscle. *P. P.* shows parietal layer that lines the fibrous pericardium. *P. C.*, pericardial cavity which in actual conditions is a very narrow space filled with pericardial fluid.

As the opposing surfaces, owing to the constant contractions of the heart, are continually sliding one upon the other, they are admirably constructed to protect the heart from any loss of power by friction.

Endocardium. — The interior of the heart is lined by a smooth, delicate membrane, called the endocardium. This pavement membrane (endothelium) lines all the cavities of the heart, and is continued into the blood-vessels, forming their innermost coat.

The cavities of the heart. — The heart is divided from the base to the apex, by a fixed partition, into a right and left half, frequently called right and left heart. The two sides of the heart have no communication with each other after birth. The right side always contains *venous*, and the left side *arterial*, blood. Each half is subdivided into two cavities, the upper, called *auricle* (atrium); the lower, *ventricle* (ventriculum). If we examine these cavities, we notice that the muscular walls of the auricles are much thinner than those of the ventricles, and the wall of the left ventricle is thicker than that of the right (the proportion being as 3 to 1). This difference in bulk is to be accounted for, as we shall see later on, by the greater amount of work the ventricles, as compared with the auricles, have to do. These cavities communicate with one another by means of constricted openings, the

auriculo-ventricular orifices, which are strengthened by fibrous rings and protected by valves.

Important orifices of the heart. — Eight large blood-vessels are connected with the heart. These eight orifices plus the two between the auricles and ventricles, make a total of ten.

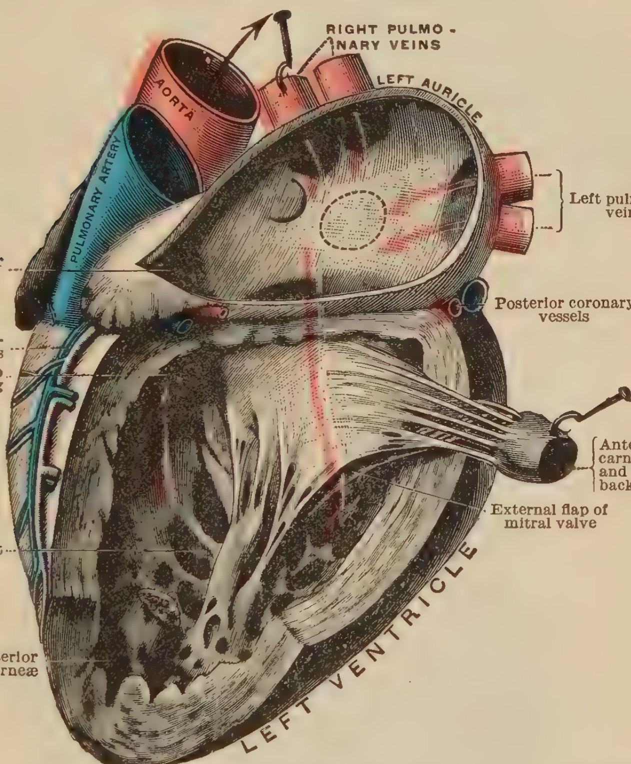


FIG. 109. — LEFT AURICLE AND VENTRICLE, THE HIND WALL OF EACH HAVING BEEN REMOVED. The columnæ carneæ are muscle columns which project from nearly the whole of the inner surface of the ventricles. Some of them give origin to the papillary muscles. (Gerrish.)

On the right side of the heart, the superior and inferior vena cava empty into the auricle, and the pulmonary artery leaves the ventricle.

On the left side of the heart, four pulmonary veins empty into the auricle, and the aorta leaves the ventricle. There are some smaller openings to receive blood directly from the heart substance, and before birth there is an opening between the right and

left auricle called the *foramen ovale.* Normally this closes as soon as the infant breathes.

Valves of the heart. — The auriculo-ventricular orifices and the openings into the aorta and pulmonary artery are guarded by valves.

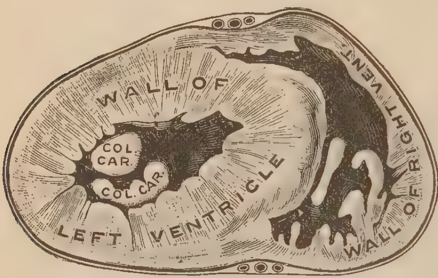


FIG. 110. — CROSS-SECTION THROUGH BOTH VENTRICLES, SHOWING THE SHAPE OF THEIR CAVITIES AND THE RELATIVE THICKNESS OF THEIR WALLS. (Gerrish.)

The tricuspid valve. — The valve guarding the right auriculo-ventricular opening is composed of three irregular-shaped flaps, or cusps, and hence is named tricuspid. The flaps are mainly formed of fibrous tissue covered by endocardium. At their bases they are continuous with one another, and form a ring-shaped membrane around the margin of the auricular opening: their pointed ends are directed downward, and are attached by cords, the *chordæ tendineæ,* to

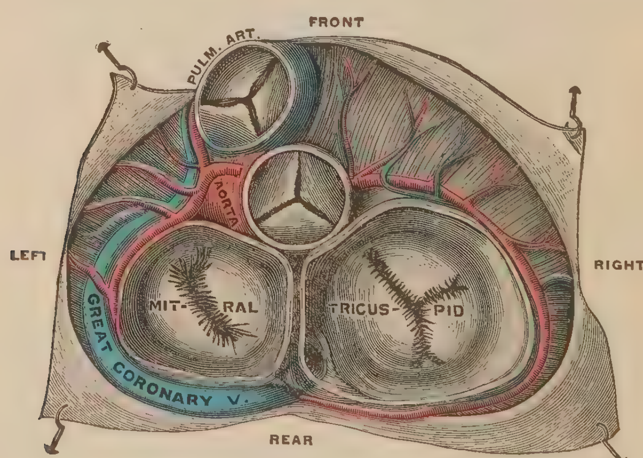


FIG. 111. — VALVES OF THE HEART AND GREAT ARTERIES, VIEWED FROM ABOVE, THE AURICLES HAVING BEEN REMOVED. (Gerrish.)

little muscular pillars, the *papillary muscles,* provided in the interior of the ventricles for this purpose.

The bicuspid valve. — The valve guarding the left auricular opening consists of only two flaps or cusps, and is named the bi-

cuspid, or mitral valve. It is attached in the same manner as the tricuspid valve, which it closely resembles in structure, except that it is much stronger and thicker in all its parts.

Function. — These valves oppose no obstacle to the passage of the blood from the auricles into the ventricles because the free edges of the flaps are pointed in the direction of the blood current; but any flow forced backward gets between the flaps and the wall of the ventricle, and drives the flaps upward, until, meeting at their edges, they unite and form a complete transverse partition between the ventricle and auricle. Being retained by the chordæ tendineæ, the expanded flaps of the valve resist any pressure of the blood which might otherwise force them to open into the auricle; at the same time the papillary muscles, to which the chordæ tendineæ are attached, contract and shorten and thus keep them taut.

Semilunar valves. — The valves between the ventricles and arteries are called the semilunar valves (*aortic and pulmonary*).

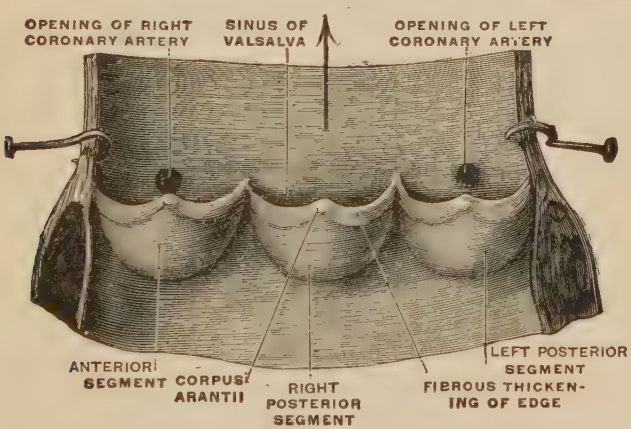


FIG. 112. — AORTIC VALVE. The artery has been cut open between the anterior and left posterior segments, and spread out. (Gerrish.)

These valves consist of three half-moon-shaped pockets, each pocket being attached by its convex border to the inside of the artery where it joins the ventricle, while its other border projects into the interior of the vessel. Small nodular bodies, called the *corpora Arantii*, are attached to the centre of the free edge of each pocket.

Function. — These valves offer no resistance to the passage of

blood from the heart into the arteries, as the free borders project into the arteries, but they form a complete barrier to the passage of blood in the opposite direction. In this case each pocket becomes filled with blood, and the free borders are floated out and distended so that they meet in the centre of the vessel. The *corpora Arantii* assist in the closure of these valves and help to make the barrier perfect.

The orifices of the heart which open into veins are not protected by valves, with the possible exception of the opening into the inferior vena cava which is partly covered by a membrane known as the Eustachian valve.

Auriculo-ventricular bundle of His. The muscular tissue of the auricles is not continuous with that of the ventricles. They

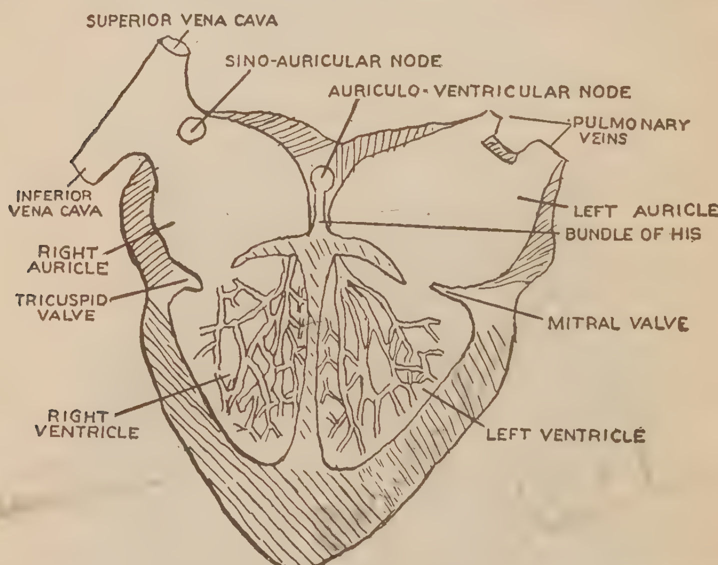


FIG. 113. — DIAGRAM OF THE AURICULO-VENTRICULAR NODE AND BUNDLE OF HIS.

are connected by fibrous tissue and the auriculo-ventricular bundle of His, which consists of muscular and nervous tissue. This bundle arises in a collection of cells known as the auriculo-ventricular node, located in the septum between the auricles. It is connected with the muscles of the auricles and also with the remnant of sinus tissue — the sino-auricular node — which is located at the mouth of the superior vena cava.[1] It passes down

[1] See page 217.

the septum between the auricles to the septum between the ventricles, where it divides into right and left bundles, one for each ventricle. In the lower part of the ventricles each bundle separates into numerous strands which spread over the entire internal surface. The terminal strands are called *Purkinje fibres.* The significance of these structures is discussed on page 230.

Blood supply. — Just after the aorta leaves the left ventricle it gives off two small branches, called the *right* and *left coronary* arteries. They encircle the heart like a crown, hence their name. They supply the substance of the heart with blood, as the blood contained within the cavities of the heart only nourishes the endocardium.

Nerve supply. — The heart is supplied (1) by the vagi nerves from the central nervous system and (2) by nerves from the sympathetic system. Stimulation of the vagi fibres slows the action of the heart. They are therefore known as cardiac inhibitors. Stimulation of the sympathetic nerves increases the force of the heart beat, therefore they are known as cardiac accelerators.

ARTERIES

The arteries are tubes that carry blood from the heart and are composed of three coats: —

1. — An inner **endothelial** lining which is continuous with the endothelium lining the heart. It furnishes a smooth, slippery surface over which the blood can flow without friction.

2. — A middle coat of **fibrous elastic tissue** with muscles interlaced and circularly disposed around the vessel. By virtue of the structure of the middle coat, the arteries are both extensile and elastic.[1] It is thicker and contains

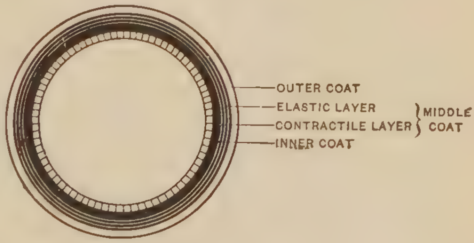


FIG. 114. — DIAGRAM OF A CROSS-SECTION OF AN ARTERY, SHOWING THE COMPOSITION OF ITS TUNICS. (Gerrish.)

[1] It is well to bear in mind the difference between extensile and elastic. By extensile we mean that an object can be stretched; by elastic that it returns to its former shape as soon as the stretching force is removed.

a larger proportion of elastic tissue in the larger arteries. In the smaller arteries it is thinner and contains a larger proportion of muscular tissue. The proper functioning of the arteries depends upon their extensibility and elasticity and may be demonstrated by the following example: —

If we tie a piece of a large artery at one end and inject fluid into the other end, the artery swells out to a very great extent, but will return at once to its former size when the fluid is let out.

The great extensibility and elasticity of the arteries adapts them for receiving the additional amount of blood thrown into them at each contraction of the heart.

3. — An outer, dense **fibrous** coat with fibres arranged longitudinally. The strength of an artery depends largely upon the outer fibrous coat; it is far less easily cut or torn than the other coats, and serves to resist undue expansion of the vessel.

The arteries do not *collapse* when empty, and when an artery is severed the orifice remains open. The muscular coat, however, contracts somewhat in the neighborhood of the opening, and the elastic fibres cause the artery to retract a little within its sheath, so as to diminish its caliber and permit a blood-clot to plug the orifice. This property of the severed artery is an important factor in the arrest of hemorrhage.

Blood and nerve supply of the arteries. — The blood which flows through the arteries nourishes only the inner coat. The middle and outer coats are supplied with arteries, capillaries, and veins, called **vasa vasorum**, or blood-vessels of the blood-vessels.

The muscular tissue found in the walls of the arteries is supplied with nerves chiefly from the sympathetic system. These nerves are called **vasomotor**, and are divided into two sets, (1) vaso-constrictor, and (2) vaso-dilator.

Stimulation of one set of these nerves (vaso-constrictor) causes contraction of the muscles and constriction of the arteries; stimulation of a second set (vaso-dilator) causes a relaxation of the muscles, and dilatation of the arteries. The widening and narrowing of the arteries not only affects the local circulation in different parts of the body, but the amount of resistance they oppose to the arterial impulse also influences in some degree the character of the heart-beat. The term "**tone of the arteries**" is used to express the normal degree of contracture of the arterial

walls. This is an inherent property which is independent of the nervous system.

Sheaths of the arteries. — The greater number of the arteries are accompanied by a nerve and one or two veins and surrounded by a sheath of connective tissue, which helps to support and hold these structures in position.

Size of the arteries. — The largest arteries in the body, the aorta and pulmonary artery, measure about one inch (2.8 cm.) in diameter, at their connection with the heart. These arteries give off branches, which divide and subdivide into smaller branches. A branch of an artery is always less than the trunk from which it springs, hence the arteries grow smaller as they subdivide, and gradually lose their characteristic structure. The smallest arteries are called *arterioles*, and at their distal ends, where only the internal coat remains, the capillaries begin.

CAPILLARIES

The capillaries are exceedingly minute vessels which average about $\frac{1}{2000}$ of an inch (.0125 mm.) in diameter. They connect the arterioles (smallest arteries) with the venules (smallest veins), thus receiving the blood from the arterioles and carrying it to the venules.

Fig. 115. — Fine Capillaries from the Mesentery. (Collins.)

Structure. — The walls of the capillaries are formed entirely of *one* layer of simple endothelium composed of flattened cells joined edge to edge by cement substance, and continuous with the layer which lines the arteries and veins.

Distribution. — The capillaries communicate freely with one another and form interlacing networks of variable form and size in the different tissues. All the tissues, with the exception of the cartilages, hair, nails, cuticle, and cornea of the eye,[1] are traversed by these networks of capillary vessels. Their diameter is so small that the blood cells must pass

[1] These parts not penetrated by the blood-vessels imbibe nutritive matter from adjacent tissues, and are just as dependent on the blood as all the other tissues.

through them in single file and very frequently the cell is larger than the caliber of the vessel, and has to be squeezed to enable it to pass through. In many parts they lie so closely together that a pin's point cannot be inserted between them. They are most abundant, and form the finest networks, in those organs where the blood is needed for purposes other than local nutrition, as, for example, secretion or absorption.

Function. — In the glandular organs the capillaries supply the substances requisite for secretion; in the alimentary canal they take up some of the elements of digested food; in the lungs they absorb oxygen and give up carbon dioxide; in the kidneys they discharge the waste products collected from other parts; all the time, everywhere through their walls, that interchange is going on which is essential to the renovation and life of the whole body. It is in the capillaries, then, that the chief work of the blood is done; and the object of the vascular mechanism is to cause the blood to flow through these vessels in the manner best adapted for accomplishing this work.

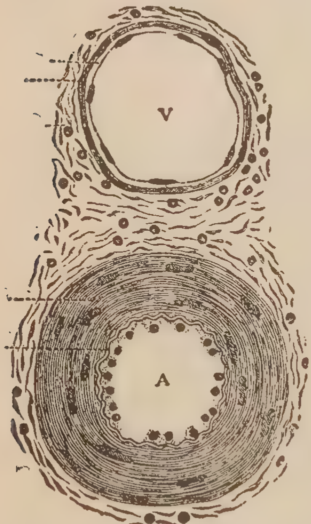


FIG. 116. — TRANSVERSE SECTION THROUGH A SMALL ARTERY AND VEIN, SHOWING THE RELATIVE DIFFERENCE IN THE THICKNESS OF THEIR WALLS. In the vein (*V*) the outer coat is thickest, in the artery (*A*) the extensile and elastic middle coat is thickest. (Klein and Noble Smith.)

VEINS

The veins are tubes that carry blood to the heart. They have three coats and on the whole resemble the arteries in structure. They differ from them in having: (1) much thinner walls (see Fig. 116); (2) they contain less elastic tissue, more white fibrous tissue, and because of this are not so elastic or contractile as the arteries; (3) many of the veins are provided with valves.

Valves. — The valves are semilunar folds of the internal coat of the veins; and usually consist of two flaps, rarely one or three. The convex border is attached to the side of the vein, and the free edge points toward the heart. Their function is to prevent

regurgitation and keep the blood flowing in the right direction, *i.e.*, toward the heart.

If for any reason the blood on its onward course toward the heart is driven backward, the refluent blood, getting between the wall of the vein and the flaps of the valve, will press them inward until their edges meet in the middle of the channel and close it.

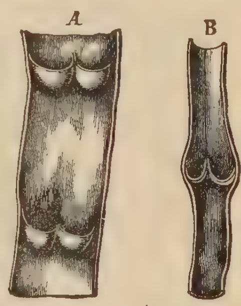


FIG. 117. — DIAGRAM SHOWING VALVES OF VEINS. *A*, part of a vein, laid open, with two pairs of valves; *B*, longitudinal section of vein, showing valves closed. (Sharpey.)

The valves are most numerous in the veins where regurgitation is most likely to occur, *i.e.*, the veins of the extremities. For the same reason a greater number are found in the lower than in the upper limbs. They are absent in many of the small veins, in the large veins of the trunk, and in veins not subjected to muscular pressure. The veins, like the arteries, are supplied with both blood-vessels and nerves; the supply, however, is far less abundant.

It must be remembered that although the arteries, capillaries, and veins have each the distinctive structure above described, it is at the same time difficult to draw the line between the arteriole and large capillary; and between the large capillary and venule. The veins on leaving the capillary networks only gradually assume their several coats, while the arteries dispense with their coats in the same imperceptible way as they approach the capillaries.

LYMPH VASCULAR SYSTEM

As the process of lymph formation is continual,[1] it follows that œdema would result from the accumulation of lymph if some system of drainage were not provided to return the lymph to the blood. This drainage system is called the lymph vascular system.

Lymph Vascular System
- **Lymph spaces**
- **Lymph vessels**
  - Lymph capillaries.
  - Lymphatics.
  - Thoracic duct.
  - Right lymphatic duct.
  - Lacteals.
  - Serous cavities.
- **Lymph nodes**

[1] See page 166.

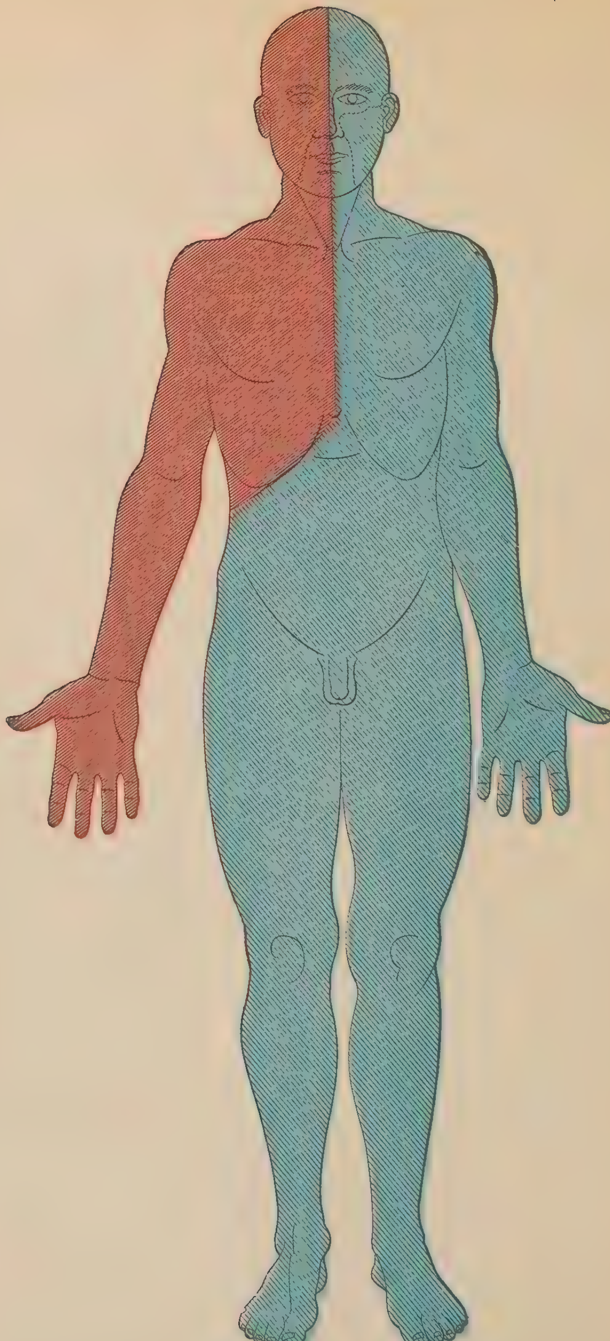


Fig. 118. — The Regions whose Lymph Flows into the Right Lymphatic Duct Are Suggested by the Red Area; those which Are Tributary to the Thoracic Duct by the Blue Area. (Gerrish.)

Lymph spaces. — The microscopic spaces which exist between the cells are always filled with lymph and are called lymph spaces. In them the lymphatics begin.

Lymph vessels. — The plan upon which the lymphatic system is constructed is similar to that of the blood vascular system, if we omit the heart and the arteries. In the lymph spaces we find the closed ends of minute microscopic vessels, called *lymph capillaries*, which are comparable to, and often larger than, the blood capillaries. These lymph capillaries unite to form larger vessels called *lymphatics*, which are comparable to the veins. The lymphatics continue to unite and form larger and larger vessels until finally they converge into two main channels, (1) the thoracic duct, and (2) the right lymphatic duct.

FIG. 119. — VALVES OF THE LYMPHATICS.

The thoracic duct. — The thoracic duct begins at the second lumbar vertebra and ascends upward to the seventh cervical. It lies in front of the bodies of the vertebræ, gradually inclining towards the left, until, on a level with the seventh cervical vertebra, it turns outward and arches downward and forward to terminate in the innominate vein at the point of junction of the left internal jugular and left subclavian.

It is from fifteen to eighteen inches (38–45 cm.) long in the adult, and is about the size of a goose quill. It receives the lymph from the left side of the head, neck, and chest, all of the abdomen and both lower limbs, also the chyle from the lacteals. It is dilated below, where it receives the lymph from the lower limbs and the chyle from the lacteals, the dilatation being known as the chyle cistern (receptaculum chyli). (See Fig. 145.)

The right lymphatic duct. — The right lymphatic duct is a short vessel, usually from one-half to one inch (1.3 to 2.5 cm.) in length. It pours its contents into the innominate vein at the junction of the right internal jugular and subclavian veins.

The lymphatics from the right side of the head, neck, the right arm, and the upper part of the trunk enter the right lymphatic duct. The parts drained by each are suggested by Fig. 118.

Structure of the lymph vessels. — The lymphatics resemble the veins in their structure as well as in their arrangement. The smallest have but a single coat of endothelioid cells, having a peculiar dentated outline. The larger vessels have three coats, similar to veins, except that they are so thin as to be transparent, and are more abundantly supplied with valves. The valves are constructed and arranged in the same fashion as those of the veins, but follow one another at such short intervals that, when distended, they give the vessel a beaded or jointed appearance. They are usually wanting in the smaller networks. The valves allow the passage of material from the smaller to the larger lymphatics, and from these into the veins, but obstruct the flow in the opposite direction.

FIG. 120. — LACTEALS AND LYMPHATICS, DURING DIGESTION. (Dalton.)

Classification of lymphatics. — The lymph, like the blood in the veins, is returned from the limbs and viscera by a superficial and a deep set of vessels. The superficial lymphatic vessels are placed immediately beneath the skin, and accompany the superficial veins. In the interior of the body the lymphatics lie in the submucous tissue throughout the whole length of the gastro pulmonary and genito-urinary tracts, and in the subserous tissue of the thoracic and abdominal cavities. The deep lymphatics, fewer in number and larger than the superficial, accompany the deep blood-vessels.

Lacteals. — The lymphatics that have their origin in the villi

of the small intestine are called lacteals. During the period of intestinal digestion they are filled with chyle, which has a white aspect, due to fat absorbed from the food, and suspended in it like oil in milk. After fasting, the lacteals contain lymph which differs very little from the lymph found in the ordinary lymphatics.

Serous cavities. — A close relationship exists between the lymphatics and the serous cavities of the body, *i.e.*, pleural, pericardial, and peritoneal; also the synovial bursæ. These cavities are lined by endothelium through which the lymph transudes by osmosis.

Function of the lymphatics. — The function of the lymphatics is to carry from the tissues to the veins all the materials which the tissues do not need. Functionally they may be considered between the capillaries and the veins, as they gather up the lymph which exudes through the thin capillary walls, and return it to the innominate veins. Here it becomes mixed with the blood, enters the superior vena cava, and then the right auricle of the heart. The function of the lacteals is to help in the absorption of digested food, especially fats.

FIG. 121. — A LYMPH NODE WITH ITS AFFERENT AND EFFERENT VESSELS. (Gerrish.)

Lymph nodes. — The lymph nodes are numerous round or ovoid bodies placed in the course of the lymphatics. They vary in size from a pinhead to an almond. A lymph node is covered by an envelope, or capsule, of connective and muscular tissue. This capsule sends fibrous bands called trabeculæ (little beams) into the substance of the node, and divides it into irregular spaces, which communicate freely with each other. The irregular spaces are occupied by a mass of cellular pulp substance, which, however, does not quite fill them as it never touches the capsule or trabeculæ, but leaves a narrow interval between itself and them. It looks as if the pulp had originally filled the framework and then shrunk away slightly on

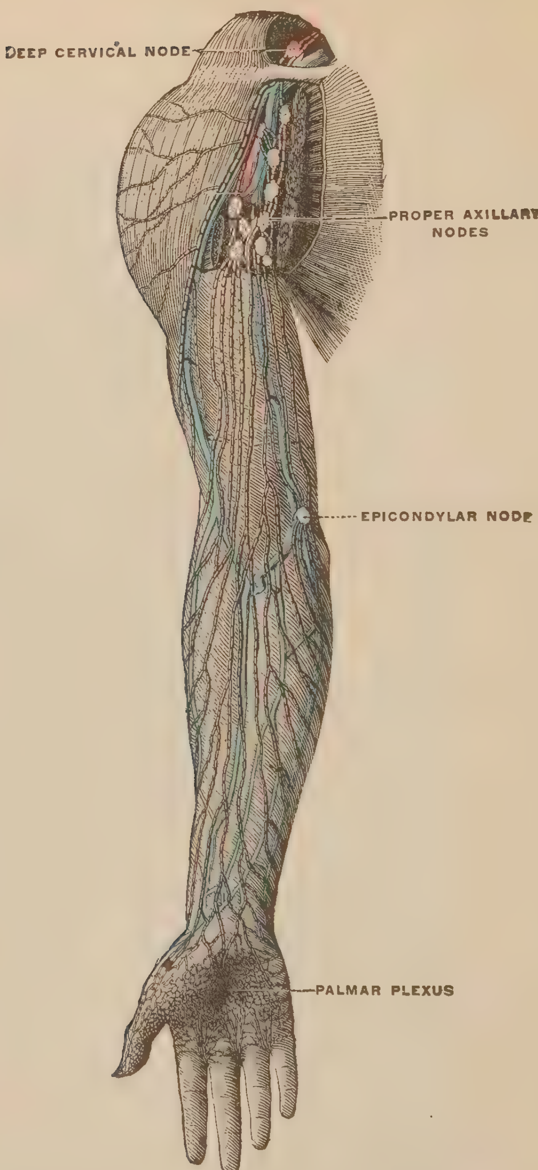


FIG. 122. — THE LYMPH NODES AND VESSELS OF THE UPPER LIMB. (Gerrish.)

all sides. The spaces thus left form channels for the passage of the lymph, which enters by afferent vessels, and, after circulating through the node, issues by efferent vessels. The substance of a lymph node is reticular adenoid tissue. They are well supplied with blood.

Location of nodes. — There is a superficial and a deep set of nodes, just as there is a superficial and a deep set of lymphatics and veins. Occasionally a node exists alone, but they are usually in groups or chains, and arranged around blood-vessels. They are found in great numbers in the neck, thorax, axilla, groin, mesentery, and alongside of the aorta, inferior vena cava, and the iliac vessels. A few are found in the popliteal space and in the arm as far as the elbow, but none farther down the leg or forearm. They are usually named from the position in which they are found in the body, viz. cervical in the neck, thoracic in the thorax, axillary in the axilla, inguinal in the groin, mesenteric in the mesentery.

FIG. 123. — THE LYMPH NODES AND VESSELS OF THE LOWER LIMB. (Gerrish.)

Function of the lymph nodes. — The lymph nodes serve two important purposes: —

(1) *As filters for the lymph.* — In this way they act as safety-valves and serve to retard the spread of infection through the body. If any portion of the body is infected, the poison may be carried by the lymphatics to their special nodes. There its course is stopped and the node may suffer enlargement or even break down and be destroyed. If the

infection is not arrested, the node next in line will suffer, then the next, and so on.

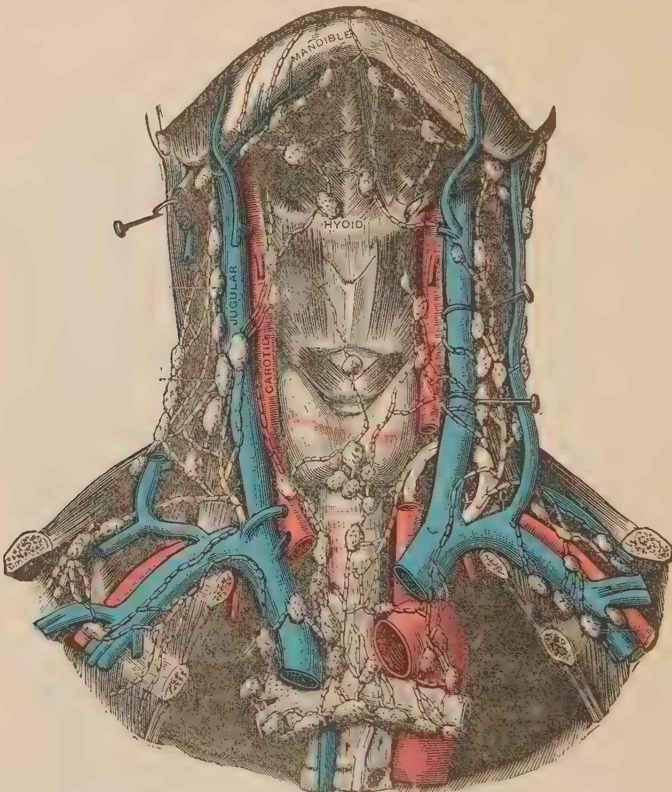


Fig. 124. — The Lymph Nodes of the Neck and Upper Part of the Thorax. (Gerrish.)

(2) *Multiplication of leucocytes.* — In its passage through the node the lymph takes up fresh leucocytes, which are continually multiplying by cell division in the substance of the node.

SUMMARY

Blood Vascular System
- Heart.
- Arteries — small arteries are named arterioles.
- Capillaries.
- Veins — small veins are named venules.

HEART
- **Location**
  - Between lungs.
  - Above diaphragm.
- **Structure**
  - Smooth lining on inside — *Endocardium.*
  - Muscle substance — *Myocardium.*
  - Outside covering — *Pericardium*
    - Fibrous portion.
    - Serous
      - Visceral.
      - Parietal.
- **Cavities**
  - **Right heart**
    - **Right auricle**
      - Receives blood.
      - Thin walls.
    - **Right ventricle**
      - Expels blood into pulmonary artery.
      - Thick walls.
  - **Left heart**
    - **Left auricle**
      - Receives blood.
      - Thin walls.
    - **Left ventricle**
      - Expels blood into aorta.
      - Very thick walls.
- **Orifices**
  - **Right heart**
    - **Right auricle**
      - Superior vena cava — returns blood from upper portion of body.
      - Inferior vena cava — returns blood from lower portion of body.
    - Auriculo-ventricular orifice between auricle and ventricle.
    - **Right ventricle**
      - Pulmonary artery — carries blood from heart to lungs.
  - **Left heart**
    - **Left auricle**
      - Two right pulmonary veins
      - Two left pulmonary veins
      - (both) Return blood from lungs.
    - Auriculo-ventricular orifice between auricle and ventricle.
    - **Left ventricle**
      - Aorta — distributes blood to all parts of body.

HEART

- **Valves**
  - **Tricuspid valve** — composed of three cusps situated in the right ventricle.
  - **Bicuspid or mitral valve** — composed of two strong, thick cusps situated in the left ventricle.
  - **Function** — Prevent flow of blood from ventricles into auricles.
  - **Semilunar valves**
    - **Aortic** — composed of three half-moon-shaped pockets between aorta and left ventricle.
    - **Pulmonary** — composed of three half-moon-shaped pockets between pulmonary artery and right ventricle.
    - **Function.** — Prevent flow of blood from arteries into ventricles.
- **Auriculo-ventricular bundle.** — Bundle of muscular and nervous tissue located in septum between right and left heart, which connects the musculature of auricles and ventricles.
- **Nerve Supply**
  - **Central nervous system.** — Vagi nerves, *inhibitory fibres*, slow the heart.
  - **Sympathetic system.** — *Accelerator fibres* increase rapidity and force of heart.
- **Blood Supply**
  - Right coronary artery
  - Left coronary artery

  } branches from aorta.

Arteries . . .
Characterized by elasticity

- **Hollow tubes** — Carry blood *from* heart.
- **Coats**
  1. Endothelial lining.
  2. Muscular and elastic tissue.
  3. Fibrous tissue.
- **Sheaths** — outside covering of connective tissue which surrounds the arteries.
- **Size** — Aorta about one inch in diameter. Arteries grow smaller as they subdivide. Smallest ones are microscopic and are called **arterioles.**

Capillaries . .
Characterized by multiplicity

- **Tiny tubes** — about $\frac{1}{2000}$ of an inch in diameter. Connect arterioles and venules.
- One coat of simple endothelium.
- Communicate freely — form networks.

Veins . . . .
Characterized by valves

- **Collapsible tubes** — smallest ones, called venules, begin where capillaries end.
- Carry blood to heart.
- Three coats, same as arteries but thinner.
- Valves — semilunar pockets.

Vaso vasorum — Term applied to blood-vessels that are supplied to coats of other blood-vessels.

Vasomotor. — Term applied to *nerves* supplied to blood-vessels
- Vaso-constrictor.
- Vaso-dilator.

- **Lymph Vascular System**
  - **Lymph spaces** — Microscopic spaces which exist between cells of which tissues are composed.
  - **Lymph vessels**
    - Lymph capillaries.
    - Lymphatics.
    - Thoracic duct.
    - Right lymphatic duct.
    - Lacteals.
    - Serous cavities.
  - **Lymph nodes**

- **Lymph Vessels**
  - **Lymph Capillaries**
    - Origin in lymph spaces.
    - One coat of endothelium — dentated.
    - Start as microscopic lymph capillaries, unite to form lymphatics. Comparable to formation of veins.
  - **Lymphatics** — three coats — numerous valves.
  - **Thoracic Duct**
    - 15 to 18 in. long. Size of goose-quill.
    - In front of vertebra from 2d lumbar to 7th cervical.
    - Has three coats — numerous valves.
    - Dilatation at lower portion called chyle cistern.
    - Receives lymph from left side of head, neck, and chest, left arm, all of abdomen, and both lower limbs. Receives chyle from lacteals.
    - Pours lymph and chyle into left innominate vein.
  - **Right Lymphatic Duct**
    - $\frac{1}{2}$ to 1 in. long.
    - Receives lymph from right side of head, neck, and chest, also right arm.
    - Pours lymph into right innominate vein.
  - **Classification**
    - **Superficial** — beneath skin, accompany superficial veins.
    - **Deep** — accompany deep blood-vessels.
  - **Lacteals**
    - Lymphatics of the intestines.
    - Many originate in villi of small intestine.
    - Contain
      - During digestion — chyle.
      - During period of fasting — lymph.
    - Absorb fatty substances.
  - **Serous Cavities**
    - Expanded lymph spaces.
    - Lymph transudes by osmosis.
  - **Function** — Drain off lymph from all parts of the body and return it to the innominate veins.

Lymph Nodes

- **Description**
  - Shape
    - Round.
    - Ovoid.
  - Size varies from pinhead to almond.
  - Outer capsule
    - Connective and muscular tissue.
  - Interior divided into irregular spaces like sponge.
  - Spaces partially filled with reticular adenoid tissue. Communicating channels for lymph, which enters by afferent, leaves by efferent vessels.
  - Are well supplied with blood.
- **Location**
  - Superficial and deep set.
  - Usually arranged around blood-vessels.
  - Neck, thorax, axilla, groin, mesentery.
  - In the arms as far as elbows.
  - In the legs as far as popliteal space.
  - Usually name indicates location.
- **Function**
  1. Filters — preventive and protective.
  2. Multiplication of leucocytes.

CHAPTER XI

THE VASCULAR SYSTEM CONTINUED: ARTERIES; PULMONARY SYSTEM; GENERAL SYSTEM; VEINS; SUPPLEMENTARY CHANNEL, AND PORTAL SYSTEM

ARTERIES

THE arteries, which carry and regulate the supply of blood from the heart to the capillaries, are distributed throughout the body in a systematic manner, and before attempting the study of the

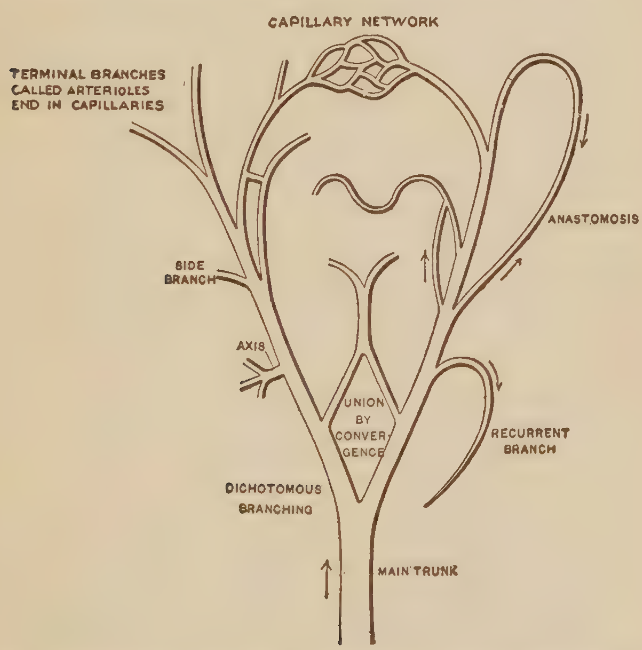


FIG. 125. — DIAGRAM SHOWING THE BRANCHINGS, ANASTOMOSES, AND CONFLUENCE OF ARTERIES. (Gerrish.)

circulation, we must try to gain a general idea of this system of distribution, in order that we may be able to locate the position of these important vessels. The arteries usually occupy *protected*

situations, that they may be exposed as little as possible to accidental injury, or to the effects of local pressure.

Division. — As they proceed in their course they divide into branches, the division taking place in different ways.

(1) An artery may at once resolve itself into two branches of nearly equal size (dichotomous division, or splitting in two).

(2) It may give off several branches in succession and still maintain its character as a trunk.

(3) It may give off one branch that divides into three equal branches. In this case the parent branch is called an axis. Example — cœliac axis.

Anastomosis or inosculation. — The distal ends of arteries unite at frequent intervals, when they are said to anastomose, or inosculate. Such inosculations admit of free communication between the currents of the blood, tend to obviate the effects of local interruption, and to promote equality of distribution and of pressure. This arrangement makes it possible to tie veins and arteries during operations, or after injuries, without serious interference with the circulation.

Plexus. — A plexus or network is formed by the inosculations of a number of arteries in a limited area. Arteries usually pursue a tolerably straight course, but in some parts of the body they are tortuous. The *facial* artery, in its course over the face, and the arteries of the lips are extremely tortuous, so that they may accommodate themselves to the movements of the parts.

Divisions of the vascular system. — The blood-vessels of the body are arranged in two main systems, namely, the pulmonary and the general or systemic.

THE PULMONARY SYSTEM

The pulmonary system is the lesser system and provides for the circulation of the blood from the right ventricle to the lungs, and then back to the left auricle. This is called the pulmonary circulation.

Blood-vessels of the pulmonary system. — The blood-vessels of the pulmonary system are (1) the pulmonary artery and all its branches, (2) the capillaries which connect these branches with the veins, and (3) the pulmonary veins.

The pulmonary artery. — The pulmonary artery conveys the venous blood from the right side of the heart to the lungs. The

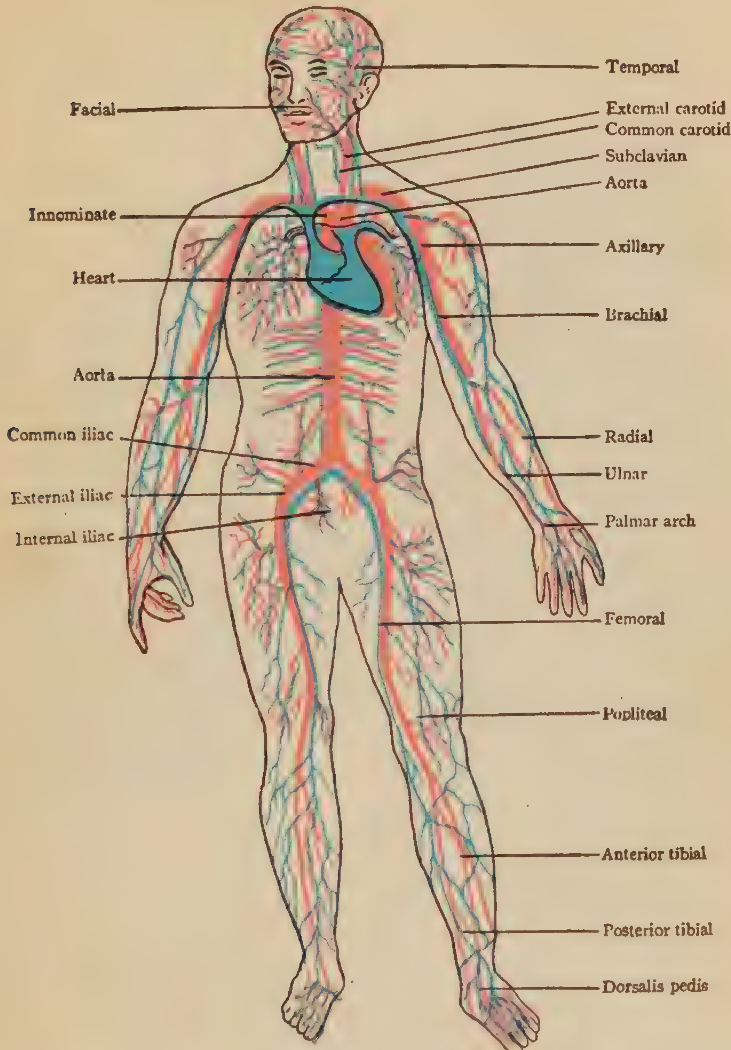


FIG. 126. — THE PRINCIPAL ARTERIES OF THE BODY. (Morrow.)

main trunk is a short, wide vessel about two inches (5 cm.) in length and a little more than one inch (about 3 cm.) in diameter. It arises from the right ventricle, in front of the aorta, and runs for a distance of two inches (5 cm.) upward, backward, and to

the left. (See Fig. 107.) On a level with the intervertebral disc, between the fifth and sixth thoracic vertebræ, it divides into two branches, the right and left pulmonary arteries which pass to the right and left lungs. From these main branches, arteries arise which divide and subdivide, grow smaller in size, and finally merge

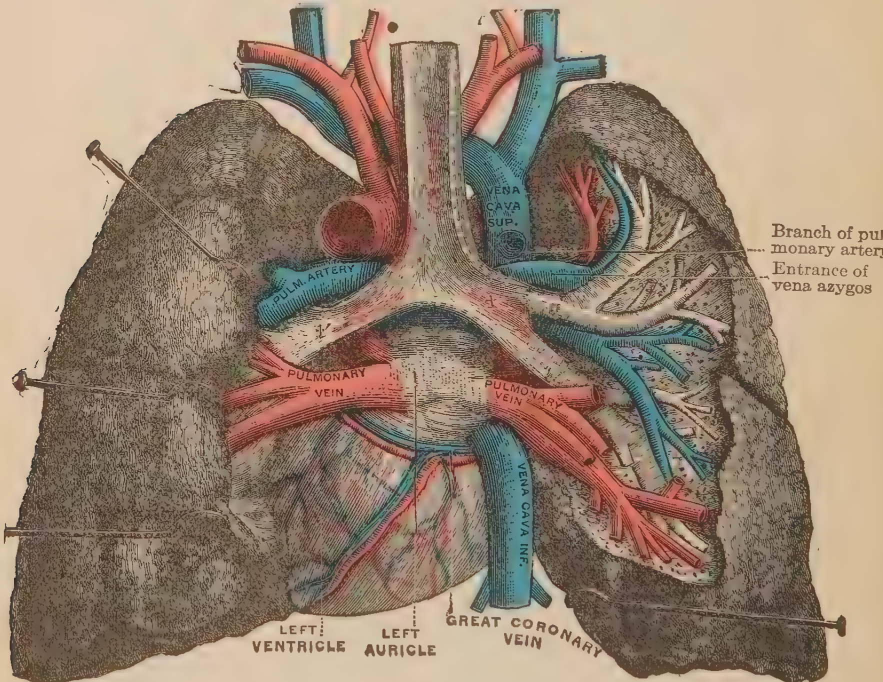


Fig. 127. — Pulmonary Veins, Seen in a Dorsal View of the Heart and Lungs. The left lung is pulled to the left, and the right lung has been partly cut away to show the ramifications of the air-tubes and blood-vessels. (Gerrish.)

into capillaries which form a network upon the walls of the air-cells.[1] These capillaries unite, grow larger in size, and gradually assume the characteristics of veins. The veins unite to form the pulmonary veins.

The pulmonary veins. — The pulmonary veins are four short trunks which convey the blood from the lungs to the left auricle, and are found, two on each side, — in the root of the corresponding lung. The pulmonary veins have no valves.

[1] See page 257.

THE GENERAL SYSTEM

The general system is the larger system and provides for the circulation of blood from the left ventricle to all parts of the body by means of the aorta and its branches, and the return to the right auricle by means of the venæ cavæ. This is called the systemic circulation.

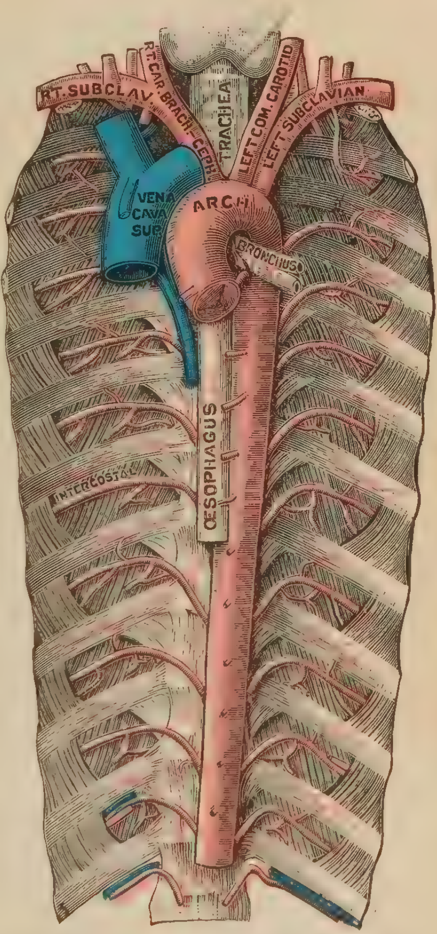


FIG. 128. — THORACIC AORTA. (Gerrish.)

The blood-vessels of the general system. — The blood-vessels of the general system consist of (1) the *aorta*, and all the arteries that originate from it, including the terminal branches called arterioles; (2) the capillaries which connect the arterioles and venules; (3) all the venules and veins of the body which empty either directly into the heart, or indirectly by means of the superior and inferior venæ cavæ.

The aorta. — The aorta is the main trunk of the arterial system. Springing from the left ventricle of the heart, it arches over the root of the left lung, descends along the vertebral column, and after passing through the diaphragm into the abdominal cavity, ends opposite the fourth lumbar vertebra by dividing into the right and left common iliac arteries. In this course the aorta forms a continuous trunk, which gradually diminishes in size from its commencement to its termination (from one and one-eighth

inches or 2.8 cm. to seven-tenths of an inch or 1.75 cm.). It gives off large and small branches at various points.

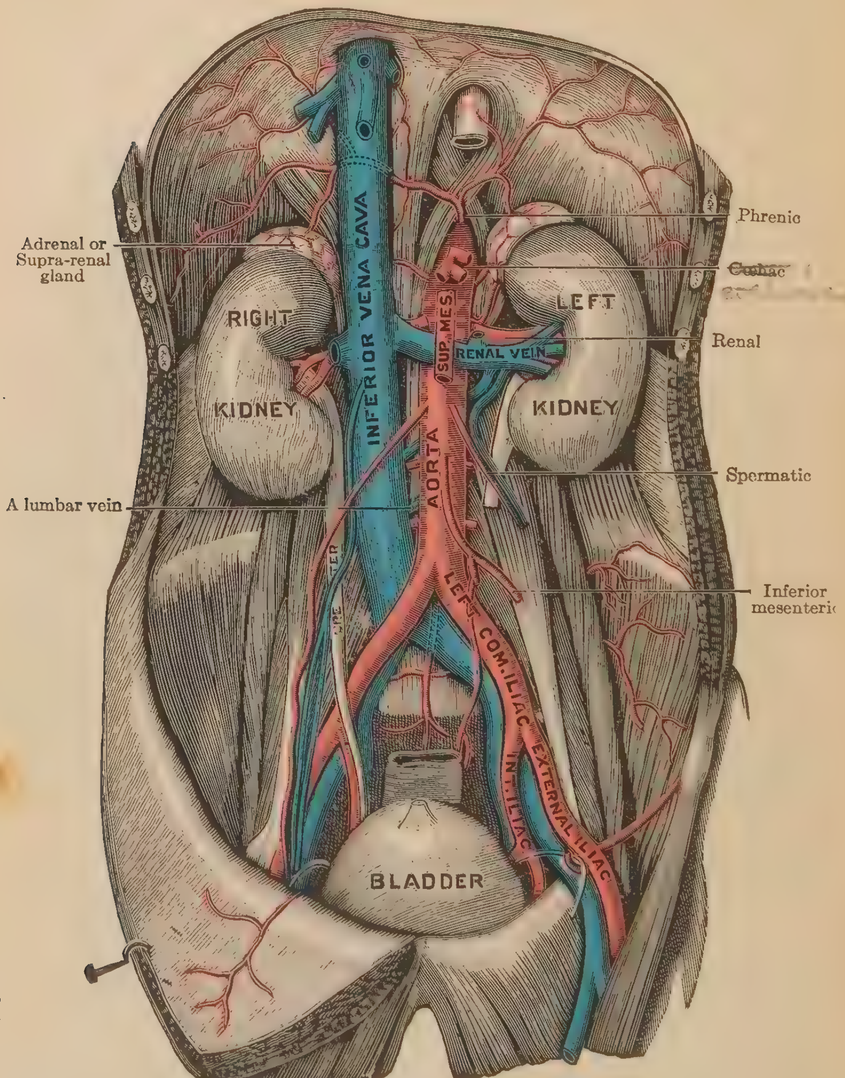


FIG. 129. — THE ABDOMINAL AORTA AND INFERIOR VENA CAVA. (Gerrish.)

It may be divided as follows: (1) the **ascending aorta** is the short part which is contained within the pericardium.

(2) The **arch** is about two inches (5 cm.) in length and extends

from the ascending aorta to the border of the fourth thoracic vertebra. It forms a well-marked curve in front of the trachea and around the root of the left lung.

(3) The **descending thoracic aorta** is the comparatively straight part that extends from the lower border of the fourth thoracic vertebra on the left side, to the aortic opening in the diaphragm in front of the lower border of the last thoracic vertebra. It has a length of from seven to eight inches (17.5 to 20 cm.).

(4) The **abdominal aorta** commences at the aortic opening of the diaphragm, in front of the lower border of the last thoracic vertebra, and terminates below by dividing into the two common iliac arteries. The bifurcation usually takes place about halfway down the body of the fourth lumbar vertebra, which corresponds to a spot on the front of the abdomen, slightly below and to the left of the umbilicus. Its length is about five inches (12.5 cm.).

Branches of the ascending aorta. — The only branches of the ascending aorta are the right and left coronary arteries. They arise immediately above the semilunar valves and encircle the heart, giving off numerous branches that supply the heart muscle. (See Fig. 112.)

Branches of the arch of the aorta. — The branches given off from the arch of the aorta are three in number — the innominate, the left common carotid, and the left subclavian arteries. (See Fig. 107.)

The **innominate** (brachio-cephalic) artery arises from the right upper surface of the arch, ascends obliquely toward the right, until, arriving on a level with the upper margin of the clavicle, it divides into the right common carotid and right subclavian arteries. Its usual length is from one to two inches (2.5 to 5 cm.). (See Fig. 107.)

The **left common carotid** arises from the middle of the upper surface of the arch of the aorta, and the right common carotid arises at the division of the innominate, consequently the left carotid is an inch or two longer than the right. They ascend obliquely on either side of the neck until, on a level with the upper border of the laryngeal prominence (Adam's apple), they divide into two great branches: (1) the external carotid, (2) the internal carotid. At the root of the neck the common carotids are separated from each other by only a narrow interval, corresponding with the width of the trachea; but as they ascend

they are separated by a much larger interval, corresponding with the breadth of the larynx and pharynx.

Each **external carotid** has eight branches, which are distributed to the throat, tongue, face, ears, and walls of the cranium.

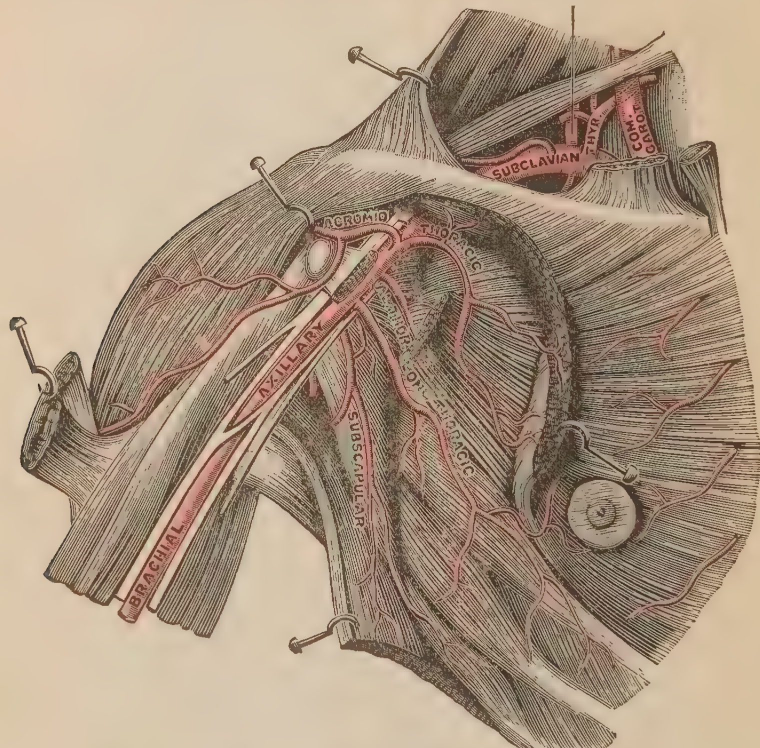


FIG. 130. — SUBCLAVIAN AND AXILLARY ARTERIES. (Gerrish.)

Each **internal carotid** has many branches which are distributed to the brain and eyes. The chief ones are the **cerebral** and **ophthalmic**.

Circle of Willis. — The circle of Willis is a remarkable anastomosis formed by the blood-vessels of the brain. It is situated at the base of the brain and is formed by the union of (1) the anterior and posterior cerebral arteries, which are branches of the internal carotid, and (2) branches of the basilar artery, which is formed by the union of the two vertebrals.[1] These arteries are joined in such

[1] The vertebral arteries are branches given off from the subclavian. They ascend on either side of the vertebral column, pass through the foramen magnum, and at the base of the brain unite to form the *basilar* artery.

a manner as to form a complete circle, and this arrangement (1) equalizes the circulation of the blood in the brain, and (2) in case of destruction of one of the arteries, provides for the blood reaching the brain through other vessels.

The subclavian arteries. — The right subclavian arises at the division of the innominate, and the left subclavian from the arch of the aorta. The subclavian arteries are the first portions of a long trunk which forms the main artery of the upper limb, and

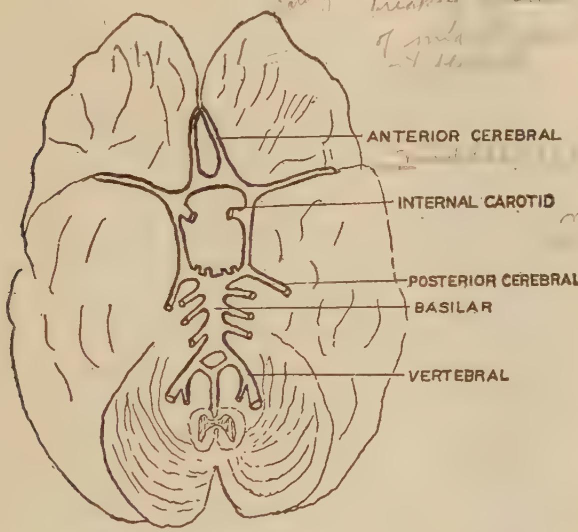


FIG. 131. — DIAGRAM OF THE CIRCLE OF WILLIS.

which is artificially divided for purposes of description into three parts; viz.: (1) Subclavian, (2) Axillary, and (3) Brachial.

The **subclavian** artery passes a short way up the thorax into the neck, and then turns downward to rest on the first rib. At the lower border of the first rib it ceases to be called subclavian, and is continued as the axillary. It gives off large branches to the brain, back, chest, and neck.

The **axillary** artery passes through the axilla, lying to the inner side of the shoulder joint and upper part of the arm. It gives off branches to the chest, shoulder, and arm.

The **brachial** artery (continuation of the axillary) extends from the axillary space to just below the bend of the elbow, where it divides into the ulnar and radial arteries. It may be readily lo-

cated, lying in the depression along the inner border of the biceps muscle. Pressure made at this point from within outward against the humerus will control the blood supply to the arm.

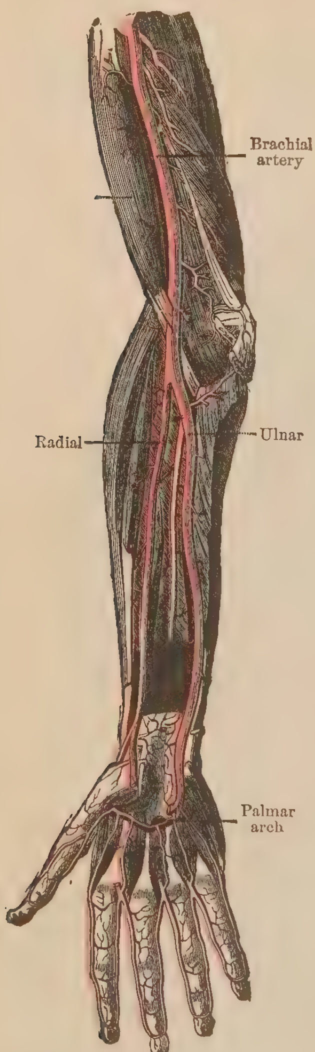


FIG. 132. — DEEP ANTERIOR VIEW OF THE ARTERIES OF THE ARM, FOREARM, AND HAND.

The **ulnar**, the larger of the two vessels into which the brachial divides, extends along the inner side of the forearm into the palm of the hand, where it terminates in the **superficial palmar arch.**

The **radial** artery appears, by its direction, to be a continuation of the brachial, although it does not equal the ulnar in size. It extends along the outer side of the front of the forearm as far as the lower end of the radius, below which it turns around the outer border of the wrist, and passes forward into the palm of the hand. It terminates in the **deep palmar arch.** The superficial and deep palmar arches anastomose and supply the hand with blood.

Branches of the thoracic aorta. — The branches derived from the thoracic aorta are numerous but small, and the consequent decrease in size is not marked. The principal branches are (1) the bronchial, (2) the œsophageal, (3) the mediastinal, (4) the pericardial, and (5) the intercostal.

(1) The **bronchial** arteries are the nutrient vessels of the lungs, and vary in number, size, and origin. As a rule, there are two left bronchial arteries and one right. The left arise from the thoracic aorta, and the right arises from the first aortic intercostal or from the left bronchial. Each vessel runs along the back part of the corresponding bronchus, dividing and subdivid-

ing along the bronchial tubes, supplying them, and the cellular tissue of the lungs.

(2) The **œsophageal** arteries are four or five in number and form a chain of anastomoses along the œsophagus. They anastomose with branches of the thyroid arteries above, and with ascending branches from the gastric and phrenic arteries below.

(3) The **mediastinal** arteries are numerous small arteries which supply the nodes and areolar tissue in the posterior mediastinum. (See page 257.)

(4) The **pericardial** arteries are small and are distributed to the pericardium.

(5) The **intercostal** arteries are ten or eleven on each side. They are subdivided into the superior and aortic intercostals. The superior intercostal artery which is a branch of the subclavian supplies the two superior intercostal spaces on each side. The aortic intercostals are usually nine in number on each side and arise from the back of the aorta. Each intercostal artery is accompanied by a vein and nerve; and each one gives off numerous branches to the muscles and skin. (See Fig. 128.)

Branches of the abdominal aorta. — Branches of the abdominal aorta may be divided into two sets: —

1. **Visceral**, or those which supply the viscera.

2. **Parietal**, or those which are distributed to the walls of the abdomen.

Visceral group. — The visceral group includes (*a*) the cœliac axis; (*b*) the right and left supra-renal; (*c*) the superior mesenteric; (*d*) the right and left renal; (*e*) the right and left spermatic or right and left ovarian; and (*f*) the inferior mesenteric.

(*a*) The **cœliac axis** is a short, wide vessel, usually not more than half an inch (1.25 cm.) in length, which arises from the front of the aorta, just below the opening in the diaphragm. It divides into three branches; viz. (1) the **gastric**, which supplies the stomach; (2) the **hepatic**, which supplies the liver and the duodenum, or portion of the intestine nearest to the stomach; and (3) the **splenic**, which supplies the spleen, and also takes part in the blood supply of the stomach and pancreas. (See Fig. 129.)

(*b*) The **supra-renal** arteries are of small size. They arise from the side of the aorta and supply the supra-renal or adrenal bodies. (See page 345 and Fig. 129.)

(*c*) The **superior mesenteric** artery arises from the fore part of the aorta, a little below the supra-renals. It supplies the small intestine beyond the first portion, and half of the large intestine. (See Fig. 129.)

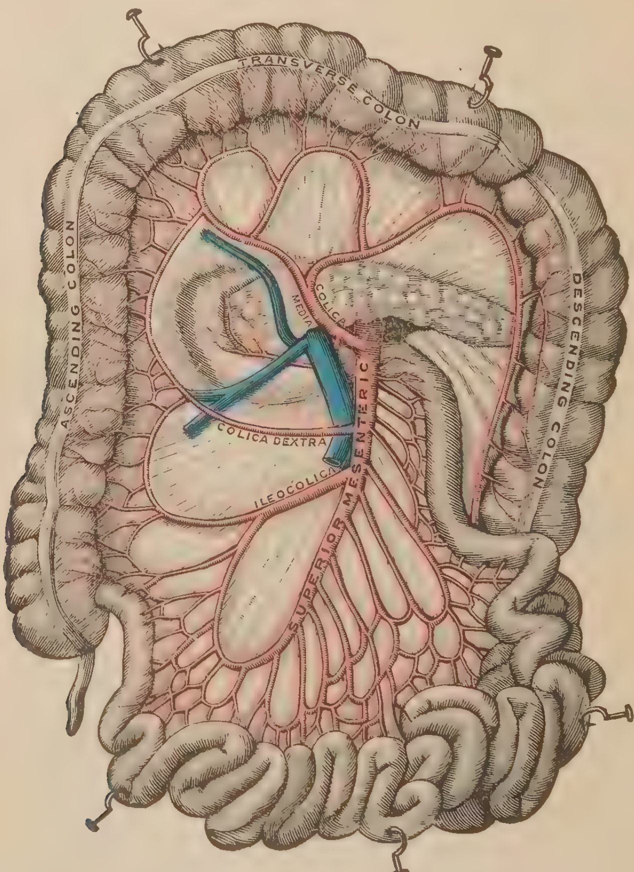


FIG. 133. — SUPERIOR MESENTERIC ARTERY. (Gerrish.)

(*d*) The **renal** arteries are of large size, in proportion to the bulk of the organs (kidneys) which they supply. They arise from the sides of the aorta, below the superior mesenteric artery, that of the right side being generally a little lower down than that of the left. Each is directed outward, so as to form nearly a right angle with the aorta. (See Fig. 129.)

(*e*) The **spermatic** arteries in the male arise close together from

the front of the aorta, a little below the renal arteries. They are distributed to the testes.

(*f*) The **ovarian** arteries in the female arise from the same portion of the aorta as the spermatic arteries in the male. They supply the ovaries, and, joined to the uterine artery, — a branch

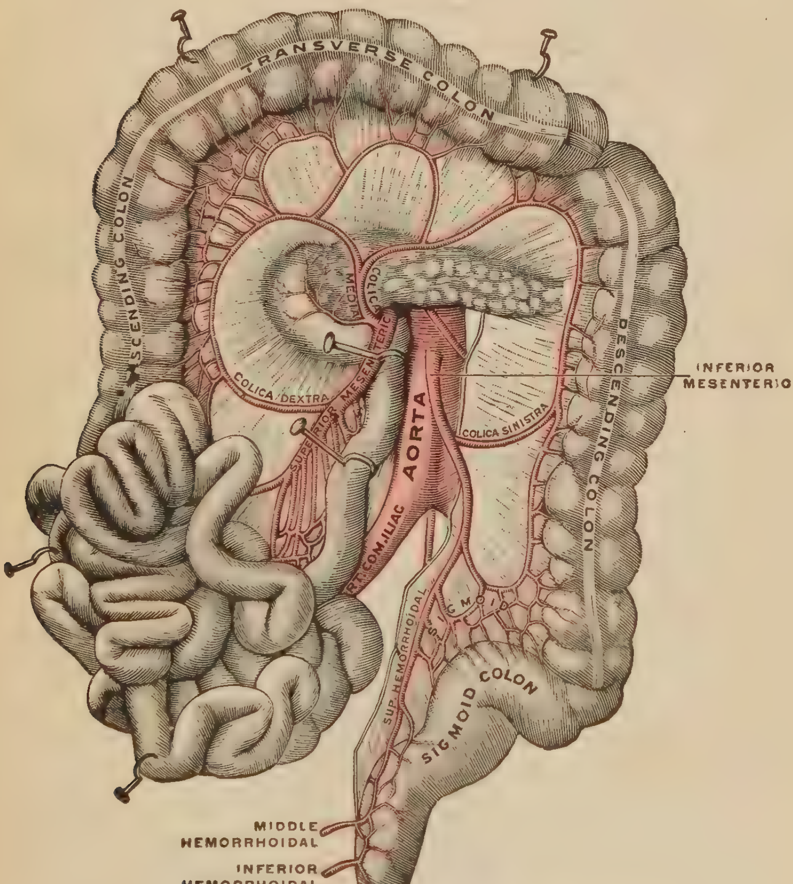


FIG. 134. — INFERIOR MESENTERIC ARTERY. (Gerrish.)

of the internal iliac, — also assist in supplying the uterus. During pregnancy the ovarian arteries become considerably enlarged.

(*g*) The **inferior mesenteric** artery arises from the front of the aorta, about an inch and a half (3.8 cm.) above its bifurcation, and supplies the lower half of the large intestine. Continued

under the name of the superior hemorrhoidal artery, it also takes part in the blood supply of the rectum. (See Fig. 129.)

Parietal group. — The parietal group includes (*a*) the right and left phrenic arteries; (*b*) the first, second, third, and fourth pairs of lumbar arteries; and (*c*) the middle sacral.

(*a*) The **phrenic** arteries arise from the aorta above the cœliac axis and are distributed to the diaphragm. (See Fig. 129.)

(*b*) The **lumbar** arteries supply the muscles and walls of the respective regions that their names suggest.

(*c*) The **middle sacral** artery arises from the lower end of the abdominal aorta and passes down to the sacrum and coccyx.

Common iliac. — The common iliac arteries, commencing at the bifurcation of the aorta, pass downward and outward about two inches (5 cm.), and then each divides into the internal (or hypogastric) and the external iliac arteries.

The **internal iliac** artery (or hypogastric) supplies branches to the pelvic walls, pelvic viscera, the external genitals, and the buttocks. The **uterine** artery in the female, which supplies the tissues of the uterus with blood, is a very important branch of the internal iliac.

The **external iliac** is placed within the abdomen, and extends from the bifurcation of the common iliac to the lower border of the inguinal ligament.

It forms a large, continuous trunk, which extends downward in the lower limb, and is named in successive parts of its course, femoral, popliteal, and posterior tibial.

The **femoral** artery lies in the upper three-fourths of the thigh, its limits being marked above by the inguinal (Poupart's) ligament and below by the opening in the great adductor muscle. After passing through this opening the artery receives the name of popliteal. In the first part of its course the artery lies along the middle of the depression on the inner aspect of the thigh, known as Scarpa's triangle.[1] In this situation the beating of the artery may be felt, and the circulation through the vessel may be most easily controlled by pressure.

[1] Scarpa's triangle is a name given to a triangular space situated on the upper, anterior, and inner surface of the thigh. It is bounded above by Poupart's ligament, on the outer side by the sartorius muscle, and on the inner side by the adductor.

The **popliteal** artery, continuous with the femoral, is placed at the back of the knee; just below the knee-joint it divides into the posterior tibial and anterior tibial arteries.

The **posterior tibial** artery lies along the back of the leg, and extends from the bifurcation of the popliteal to the ankle, where it divides into the **internal** and **external plantar** arteries.

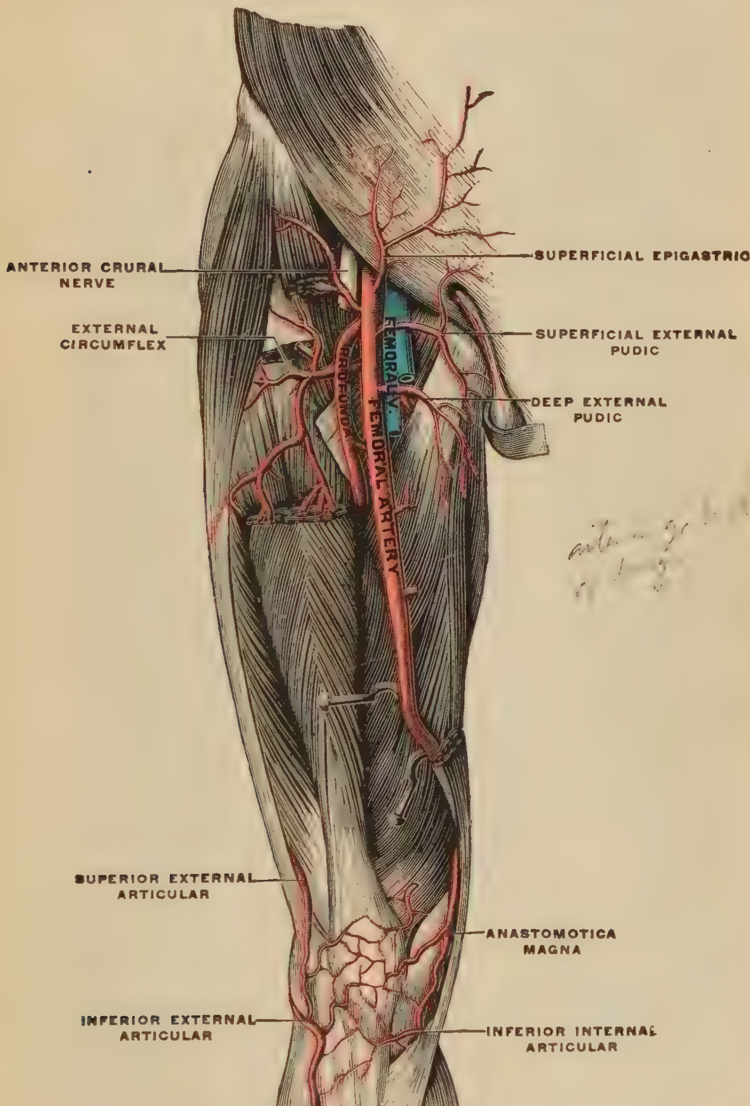


FIG. 135. — FEMORAL ARTERY. (Gerrish.)

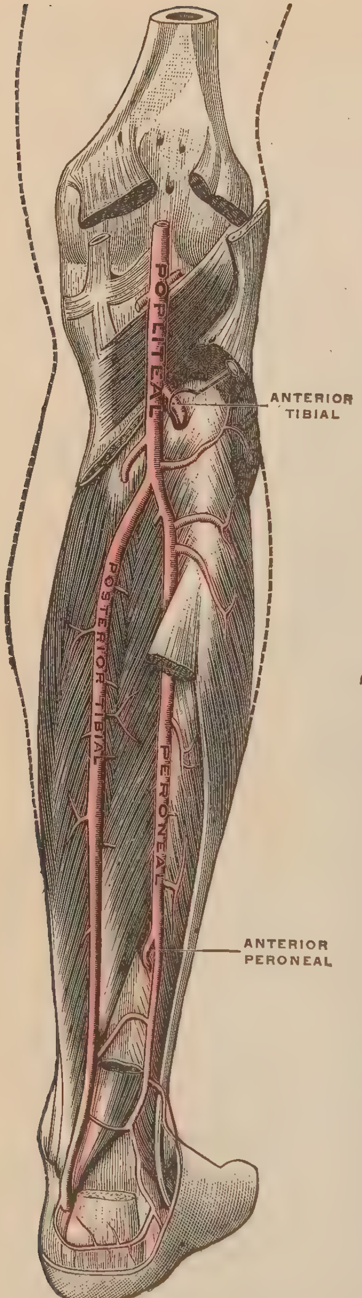


FIG. 136. — ARTERIES IN THE DORSAL PART OF THE LEG. (Gerrish.)

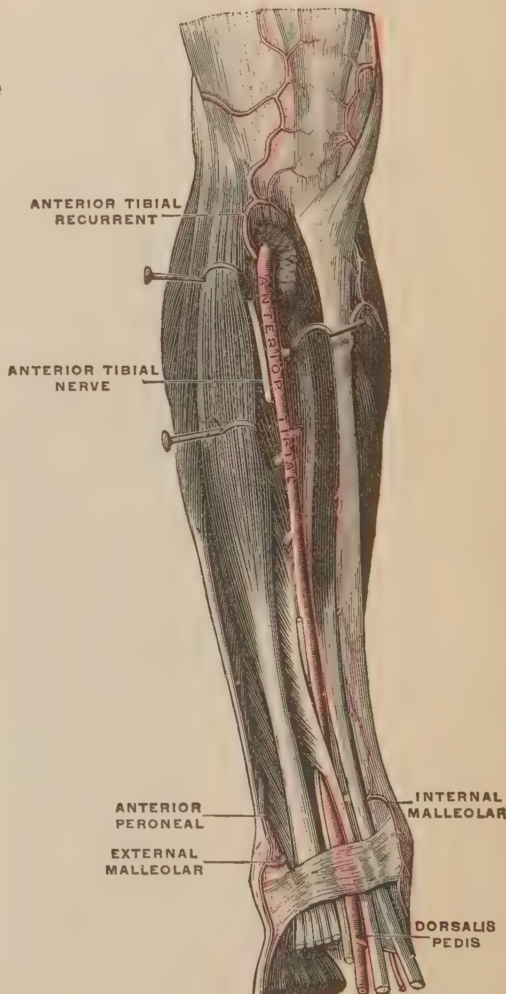


FIG. 137. — ANTERIOR TIBIAL ARTERY. (Gerrish.)

The **peroneal** artery is a large branch given off by the posterior tibial just about an inch (25 mm.) below the bifurcation of the popliteal.

The **anterior tibial** artery, the smaller of the two divisions of the popliteal trunk, extends along the front of the leg to the bend of the ankle, whence it is prolonged into the foot under the name of the **dorsalis pedis** artery. This unites with the external and internal plantar arteries to form the **plantar arch** which supplies blood to the foot.[1]

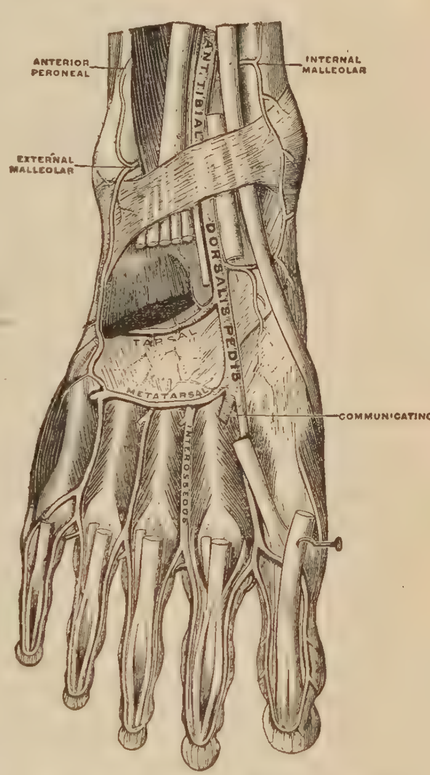


FIG. 138. — ARTERIES OF THE DORSUM OF THE FOOT. Of the dorsal interosseous only the second is labelled. (Gerrish.)

VEINS

The arteries begin as large trunks, which gradually become smaller and smaller until they end in arterioles, which merge into capillaries, while the veins begin as small branches called venules which at first are scarcely distinguishable from the capillaries, and unite to form larger and larger vessels. They differ from the arteries in their larger capacity, greater number, thinner walls, and in the presence of valves which prevent backward circulation. The veins may be divided into two sets — a superficial and a deep set.

The **superficial set** — are found immediately beneath the skin.

The **deep set** — accompany the arteries and are usually called by the same names.

[1] Drawing the outline of the aorta with its branches as an arterial tree will greatly aid the student in mastering the arterial distribution.

Sometimes two deep veins accompany an artery, and are then called **venæ comites**, or companion veins, or one vein may accompany an artery, and then be known as the **vena comes** of that artery. The superficial and the deep veins have very frequent communications with each other, and the anastomoses of veins are always more numerous than those of arteries.

The systemic veins. — The systemic veins are naturally divided into two groups: —

1. Those from which the blood is carried to the heart by the **superior vena cava**, viz. the veins of the head, neck, upper extremities, and the walls of the thorax. In this group we include the veins of the heart, which, however, pass directly into the right auricle without entering the superior vena cava.

2. Those from which the blood is carried to the heart by the **inferior vena cava**, viz. the veins of the lower limbs, the lower part of the trunk, and the abdominal viscera.

(1) Superior vena cava group.

Veins of the head and neck. — The blood returning from the head and neck flows on each side into two principal veins, the external and internal jugular.

External jugular veins. — The right and left external jugular veins are formed in the substance of the parotid glands by the union of two of the veins of the face. This union takes place on a level with the angle of the lower jaw, and each vein descends almost vertically in the neck to its termination in the subclavian. These two veins receive the blood from the face and the exterior of the cranium.

Internal jugular veins. — These veins begin at the base of the skull and descend on either side of the neck, first with the external carotid, then with the common carotid, and join at a right angle with the subclavian to form the innominate (brachio-cephalic) vein. They receive the blood from the veins and sinuses of the cranial cavity. (See Fig. 141.)

Sinuses. — The blood from the interior of the skull is returned to the large veins by venous channels that are called sinuses. They are formed by a separation of the layers of the dura mater, the fibrous membrane which covers the brain. Their outer wall consists of the dura mater, and their inner lining of endothelium

is continuous with the lining membrane of the vessels that communicate with them. (See Fig. 202.)

Veins of the upper extremities. — The blood from the upper limbs is returned by a deep and a superficial set of veins. The deep veins are the venæ comites of the forearm and arm and are

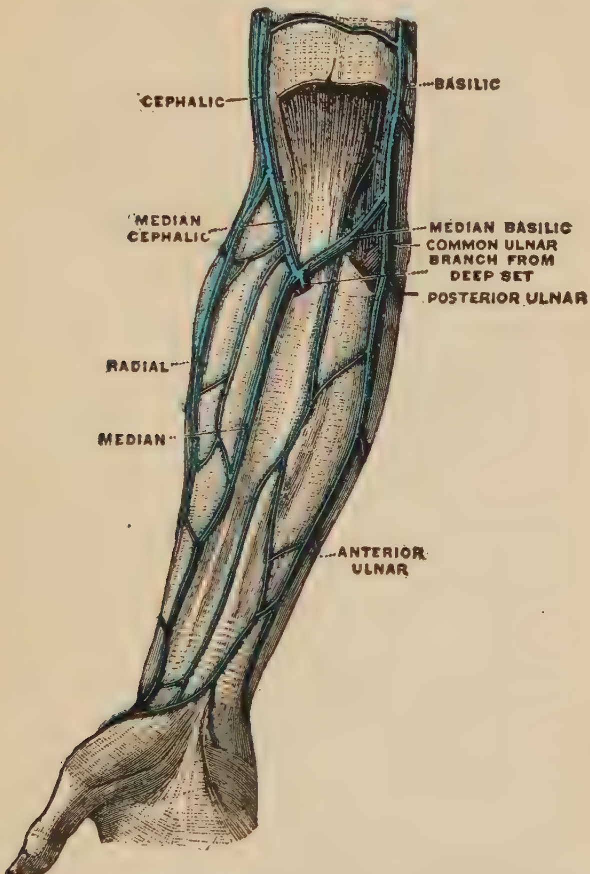


FIG. 139. — SUPERFICIAL VEINS OF FRONT OF FOREARM AND LOWER PART OF ARM. (Gerrish.)

called by the same names as the arteries. They communicate with the superficial veins at the hand and elbow, and the vena comes of the brachial artery unites with a superficial vein, *i.e.*, the basilic, to form the axillary vein.

The superficial veins. — The superficial veins are much larger than the deep, and take a greater share in returning the blood,

especially from the distal portion of the limb. They commence in two plexuses, one on the back of the hand and one on the front of the wrist. They comprise the following: —

(1) The **radial** vein begins in the dorsal plexus and runs up the radial side of the forearm to a little above the bend of the elbow, where it joins the median cephalic vein to form the cephalic.

(2) The **posterior ulnar** begins in the dorsal plexus and extends upward along the back part of the ulnar side of the forearm. Near the bend of the elbow it usually receives the anterior ulnar vein.

(3) The **anterior ulnar** vein ascends from the wrist along the ulnar side of the front of the forearm.

(4) The **common ulnar** is formed by the union of the anterior and posterior ulnar veins just below the elbow, and after a short course it joins the median basilic.

(5) The **median** vein begins in the plexus on the wrist and ascends along the front of the forearm to the bend of the elbow where it bifurcates into the median basilic and median cephalic veins.

(6) The **median basilic** is directed upward and joins the common ulnar to form the basilic vein. The median basilic is the vein usually chosen for the operation of phlebotomy or intravenous infusion.

(7) The **median cephalic** vein is directed upward and joins the radial vein to form the cephalic.

(8) The **basilic** vein ascends in the groove on the inner side of the biceps. It unites with the inner vena comes of the brachial artery to form the axillary vein.

(9) The **cephalic** vein ascends in the groove external to the biceps and ends in the axillary vein.

The axillary vein. — The axillary vein begins at the junction of the inner brachial and the basilic, and ends at the outer border of the first rib, in the subclavian. This vein accompanies the axillary artery and collects all the blood of the upper extremities.

The subclavian vein. — This vein continues the axillary from the first rib to the joint between the sternum and clavicle, where it unites with the internal jugular to form the innominate vein.

The innominate veins. — The innominate (brachio-cephalic) veins, commencing on each side by the union of the subclavian and internal jugular, transmit the blood returning from the head and neck, the upper limbs, and a part of the thoracic wall; they end below by uniting to form the superior vena cava. Both innominate veins are joined by many side tributaries; they also

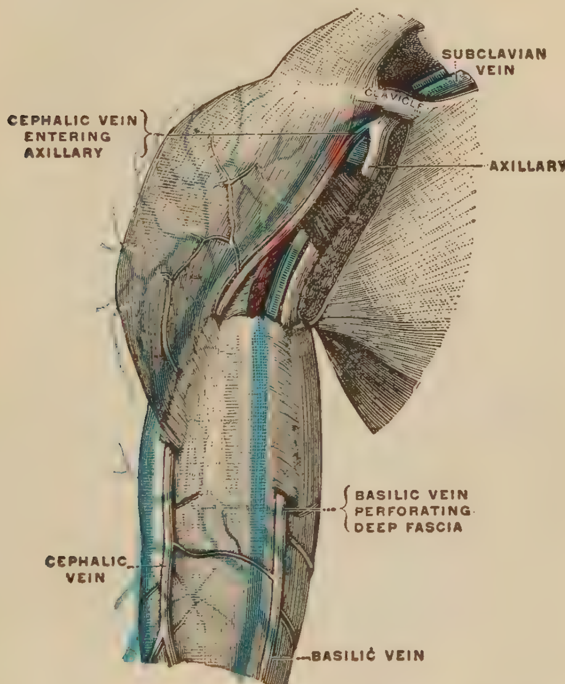


FIG. 140. — SUPERFICIAL VEINS OF FRONT OF ARM AND SHOULDER. (Gerrish.)

receive, at the junction of the subclavian and internal jugular, the lymph; on the left side from the thoracic duct, and on the right from the right lymphatic duct.

The superior vena cava. — The superior, or descending, vena cava, is formed by the union of the right and left innominate veins, just behind the junction of the first right costal cartilage with the sternum. It is about three inches (7.5 cm.) long, and opens into the right auricle, opposite the third rib.

Thoracic veins. — The great majority of the thoracic veins follow the same course as the arteries, and bear the same names.

Two exceptions are the inferior vena cava and the azygos veins which will be described later.

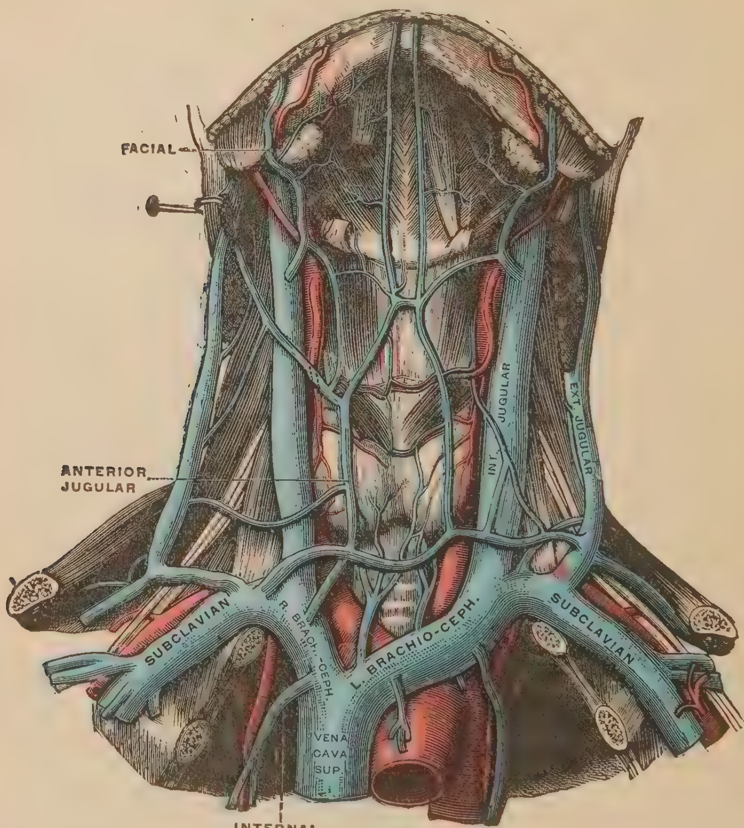


FIG. 141. — VEINS OF THE NECK AND UPPER PART OF THORAX. Front View. (Gerrish.)

(2) **The inferior vena cava group.**

Veins of the lower extremities. — The blood from the lower limbs is also returned by a deep and a superficial set of veins. They are more abundantly supplied with valves than the veins of the upper limbs.

The deep veins. — Below the knee the deep veins accompany the arteries in pairs, as venæ comites, and as in the upper limbs are called by the same names. The veins from the foot empty into *anterior tibial* and *posterior tibial* veins. They unite to form the

single *popliteal* vein, which is continued as the *femoral* and becomes the *external iliac.*

The superficial veins. — The internal or long saphenous and the external or short saphenous are the two largest superficial veins.

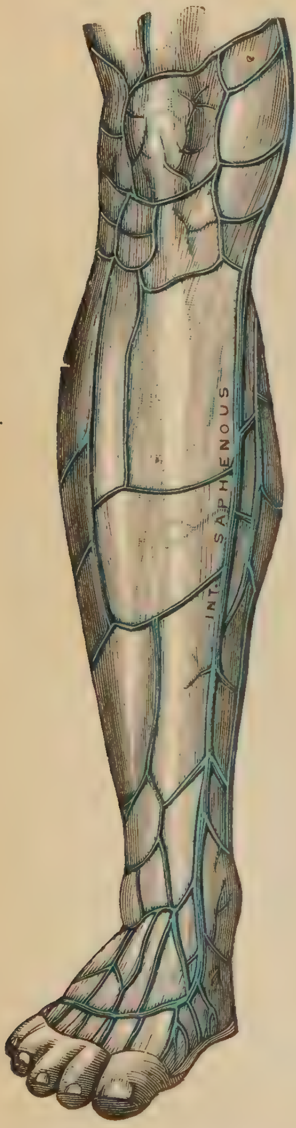


FIG. 142. — SUPERFICIAL VEINS OF THE FRONT OF THE LEG AND FOOT. (Gerrish.)

FIG. 143. — SUPERFICIAL VEINS OF THE FRONT OF THE RIGHT THIGH. (Gerrish.)

The **internal saphenous** extends from the ankle to within an inch and a half (3.8 cm.) of the inguinal ligament. It lies along the inner side of the leg and thigh and terminates in the femoral vein.

FIG. 144. — SUPERFICIAL VEINS OF THE DORSUM OF THE LEG. (Gerrish.)

The **external saphenous** arises from the sole of the foot, and, passing up the back of the leg, ends in the deep popliteal.

The femoral veins. — These vessels are a continuation of the popliteal veins and extend from the opening in the adductor magnus to the level of the inguinal ligament.

The external iliacs. — These vessels are a continuation of the femoral veins, and extend from the level of the inguinal (Poupart's) ligament, on either side, to the joint between the sacrum and the ilium. They receive the blood from the deep and superficial veins of the lower limbs. (See Fig. 129.)

The internal iliacs. — They are formed by the union of veins corresponding to the branches of the internal iliac arteries. They accompany the internal iliac arteries and unite with the external iliac veins to form the common iliacs. (See Fig. 129.)

The common iliacs. — The common iliacs extend from the base of the sacrum to the fourth lumbar vertebra, and then the two common iliacs unite to form the inferior vena cava. (See Fig. 129.)

The inferior vena cava. — The inferior, or ascending, vena cava, returns the blood from the lower limbs, pelvis, and abdomen. It begins at the junction of the two common iliacs, and thence ascends along the right side of the aorta, perforates the diaphragm, and terminates by entering the right auricle of the heart. The inferior vena cava receives many tributaries, the chief of which are the lumbar, ovarian, renal, and hepatic veins. (See Fig. 129.)

Supplementary channel. — A supplementary channel between the inferior and superior vena cava is formed by the azygos veins. They are three in number and lie on the sides of the front of the vertebral bodies.

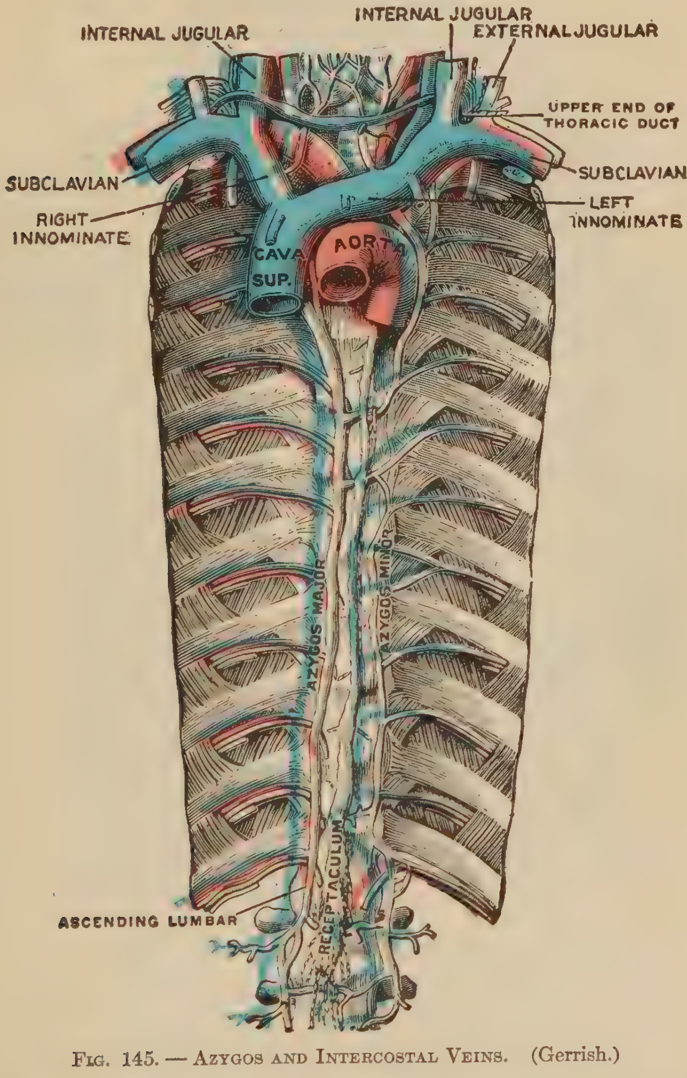


FIG. 145. — AZYGOS AND INTERCOSTAL VEINS. (Gerrish.)

The **right** or **major azygos** vein is an upward continuation of the lumbar vein which communicates with the common iliac vein, and often with the inferior vena cava and renal vein. It ascends

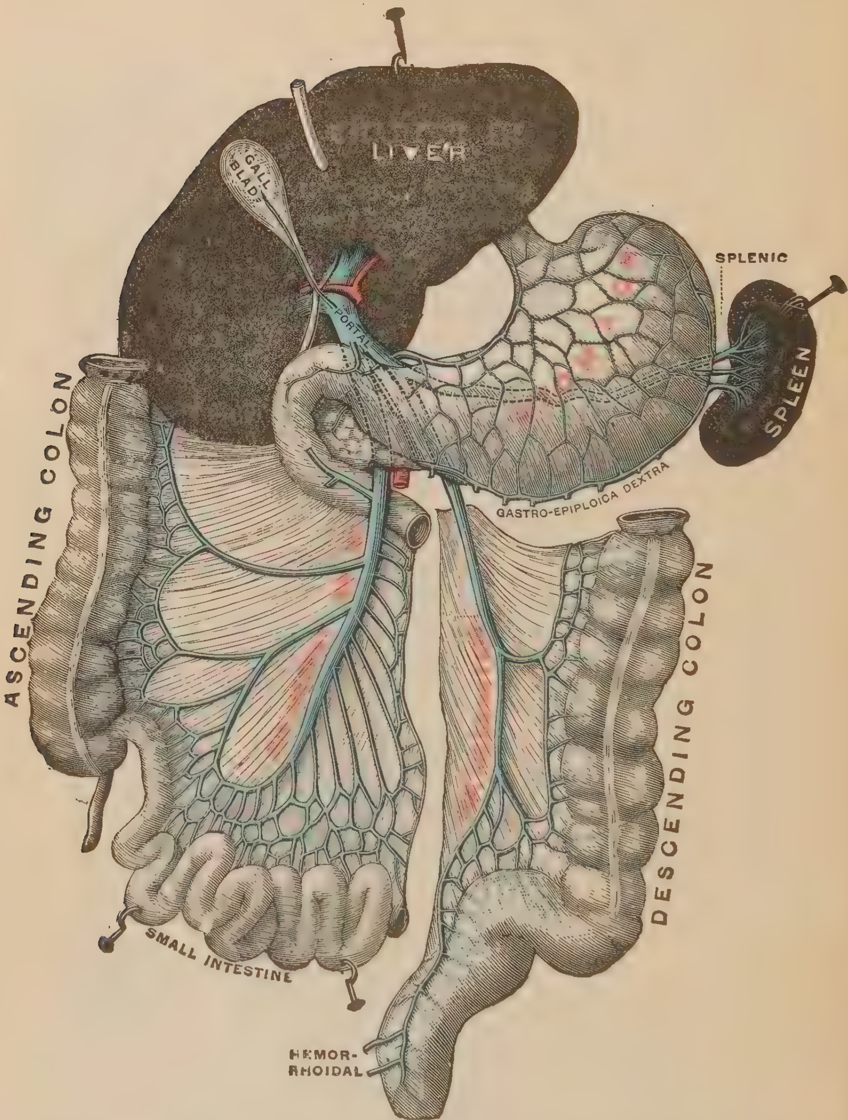


Fig. 146. — Portal System of Veins. The liver is turned upward and backward, and the transverse colon and most of the small intestines are removed. (Gerrish.)

on the right side of the vertebral column to the level of the fourth thoracic vertebra, where it empties into the superior vena cava.

The **left lower azygos** (minor) vein commences on the left side of the abdomen in a manner similar to the right. It ascends on the left side of the vertebral column, and at about the level of the eighth thoracic vertebra it connects with the right azygos vein.

The **left upper azygos** vein connects above with the superior intercostal vein, and opens below into either the left lower azygos, or the major azygos vein. These veins receive many tributaries from the thoracic walls and so are often grouped with the thoracic veins.

It is important to remember that in case of obstruction in the inferior vena cava these veins form a supplementary channel by which blood can be conveyed from the lower part of the body to the heart.

The portal system. — The gastric, splenic, inferior, and superior mesenteric veins which bring back the blood from the intestinal tract do not take it directly to the inferior vena cava. Just back of the pancreas, the splenic and superior mesenteric unite to form the portal vein, and the gastric and inferior mesenteric empty into it. The portal vein runs upward and to the right for about three inches (7.5 cm.), then enters the liver, where it divides into many small veins, and these finally form plexuses of capillaries. These capillaries unite with another set of capillaries which arise from the hepatic artery, and form the hepatic vein, which carries the blood from the liver to the inferior vena cava. Thus it will be seen that the liver receives blood from two sources — (1) the portal vein which carries blood to the liver in order that certain chemical changes may take place, and (2) the hepatic artery which carries blood to the liver for nutritive purposes. The blood from both sources of supply is carried from the liver by the hepatic vein.

The portal vein and all its branches constitute the portal system, which is often described as a third or accessory system.

SUMMARY

- **Arteries**
  - Begin as large trunks, grow smaller.
  - Usually deep seated for protection.
  - Division
    - Two branches of nearly equal size.
    - Trunk gives off several branches.
    - One branch that serves as an axis.
  - Anastomosis or inosculation — distal ends unite.
  - Plexus — many inosculations within limited area.
  - Usually straight (facial and uterine are tortuous).

- **Divisions of the Vascular System**
  - **Pulmonary System**
    - Provides for pulmonary circulation.
    - 1. Pulmonary artery
      - Right pulmonary artery — right lung.
      - Left pulmonary artery — left lung.
    - 2. Capillaries connect arterioles and venules.
    - 3. Four pulmonary veins — two from each lung.
  - **General System**
    - Provides for systemic circulation.
    - 1. Aorta and all its branches.
    - 2. Capillaries connect arterioles and venules.
    - 3. Veins empty into heart either directly or by means of inferior and superior vena cava.

- **Aorta**
  - **Ascending Aorta**
    - Right and left coronary — supply the heart.
  - **I. Arch of Aorta 2 in.**
    - Innominate 1 to 2 in.
      - Right common carotid
        - Int. carotid — brain and eye.
        - Ext. carotid — throat, tongue, face, ears, walls of cranium.
      - Right subclavian, — axillary — brachial
        - Ulnar
          - Superficial palmar arch.
        - Radial
          - Deep palmar arch.
    - Left common carotid — same branches as right common carotid.
    - Left subclavian — same branches as right subclavian.
  - **II. Thoracic Aorta 7 to 8 in.**
    - Bronchial — to the lung tissue.
    - Œsophageal — to the œsophagus.
    - Mediastinal — to the nodes and areolar tissue in the mediastinum.
    - Pericardial — to the pericardium.
    - Intercostal — to the intercostal spaces.

- **Aorta**
  - Diaphragm muscle is dividing line between thoracic and abdominal aorta.
  - **III. Abdominal Aorta 5 in.**
    - **Visceral Group**
      - Cœliac axis
        - Gastric — stomach.
        - Hepatic — liver and duodenum.
        - Splenic — spleen, stomach, and pancreas.
      - Supra-renal — supra-renal bodies.
      - Sup. mesenteric
        - Small intestine, except duodenum.
        - Half of large intestine.
      - Renal — kidneys.
      - Spermatic — testes.
      - Ovarian — ovaries and uterus.
      - Inf. mesenteric
        - Lower half of large intestine and rectum.
    - **Parietal Group**
      - Phrenic — diaphragm.
      - Lumbar — dorsal, spinal, and abdominal walls.
      - Middle sacral — sacrum and coccyx.

- **Common Iliac Arteries 2 in.**
  - Internal iliac — walls and viscera of pelvis.
  - External iliac — femoral popliteal
    - Posterior tibial
      - Ext. plantar, Int. plantar — Plantar arch.
      - Peroneal.
    - Anterior tibial
      - Dorsalis pedis.

- **Veins**
  - Begin small, grow larger.
  - Differ from arteries
    - Larger capacity.
    - Greater number.
    - Thinner walls.
    - Valves.
    - More frequent anastomosis.
  - Sets
    - Superficial.
    - Deep
      - Venæ comites — companion veins.
      - Vena comes — companion vein.

- **Superior Vena Cava Group**
  - **External Jugular Veins**
    - Receive blood from the face and the exterior of the cranium.
    - Formed in parotid gland, terminate in the subclavian.
  - **Internal Jugular Veins**
    - Receive blood from the veins and sinuses of the cranial cavity.
    - Begin at base of skull, unite with subclavian.

Superior Vena Cava Group

- **Axillary Veins**
  - (1) Receive blood from the deep veins of the forearm and arm. They accompany the arteries and are called by the same names.
  - (2) Receive blood from superficial veins
    - Radial.
    - Posterior ulnar.
    - Anterior ulnar.
    - Common ulnar.
    - Median.
    - Median basilic.
    - Median cephalic.
    - Basilic.
    - Cephalic.
  - Formed by union of the inner brachial and basilic, end in the subclavian.
- **Subclavian Veins**
  - Continuation of axillary from first rib to the joint between the sternum and clavicle.
  - Unite with internal jugular to form innominate.
- **Innominate Veins**
  - Transmit blood from head, neck, upper limbs, and part of thoracic wall. Receive lymph.
  - Formed by union of internal jugular and subclavian.
  - One on each side of body.
- **Superior Vena Cava**
  - Formed by union of right and left innominate veins. Three inches long.
  - Opens into right auricle.

Thoracic Veins — Majority follow same course and bear same name as arteries.

Inferior Vena Cava Group

- **Femoral Veins**
  - Continuation of the popliteal and extend from opening in adductor magnus muscle to the inguinal ligament.
  - (1) Receive blood from deep veins of foot, leg, and thigh. They accompany the arteries and are called by the same names.
  - (2) Receive blood from the superficial veins, two are important
    - Internal saphenous.
    - External saphenous.
- **External Iliacs**
  - Continuation of femoral veins. Extend from inguinal ligament to the joint between sacrum and ilium.
- **Internal Iliacs**
  - Formed by union of veins corresponding to branches of internal iliac artery.
- **Common Iliacs**
  - Formed by union of external and internal iliacs. Extend from base of sacrum to the fourth lumbar vertebra.
- **Inferior Vena Cava**
  - Formed by union of the common iliacs.
  - Extends from fourth lumbar vertebra to the right auricle of the heart.
  - Receives many tributaries corresponding to arteries given off from the aorta.

- **Supplementary Channel**
  - 1. Right azygos vein
  - 2. Left lower azygos vein
  - 3. Left upper azygos vein
  - Connect with superior vena cava above, and inferior vena cava below.
- **Portal Circulation**
  - **Portal Vein**
    - Splenic vein and superior mesenteric vein — Unite to form portal vein.
    - Gastric vein and inferior mesenteric vein — Empty into the portal vein before it enters the liver.
    - Carries blood to liver, breaks up into capillaries, then unites with capillaries from hepatic artery to form hepatic vein.
  - **Hepatic Vein** — empties into inferior vena cava.

CHAPTER XII

THE VASCULAR SYSTEM CONTINUED: THE GENERAL CIRCULATION; BLOOD PRESSURE; THE PULSE; LYMPH; FŒTAL CIRCULATION

THE GENERAL CIRCULATION OF THE BLOOD

THE blood is contained in a closed set of tubes which it completely fills. Interposed in this set of tubes is the heart which fills with blood from the veins and then contracts, thereby forcing a part of this blood into the lungs and a part to all the rest of the body.

To trace the general circulation, we will begin with the venous blood which is returned to the right auricle by the superior and inferior venæ cavæ. It enters and fills the right auricle, and the right ventricle which for the time being may be thought of as a single chamber, with the tricuspid valve open.[1] Then the auricle contracts and forces the blood over the open valve into the ventricle, which has already been passively filled, and now becomes well distended by the extra supply. The blood gets behind the cusps of the tricuspid valve and closes them. After a brief pause, (possibly $\frac{1}{10}$ of a second) the ventricle contracts and forces the blood over the open semilunar valves into the pulmonary artery. The pulmonary artery divides into two branches and carries the blood to the lungs, where it passes through the innumerable capillaries that surround the alveoli or air sacs of the lungs. These capillaries unite to form veins, and these unite to form larger veins, until finally two pulmonary veins return the blood from each lung to the left auricle and ventricle. The left auricle now contracts and forces the blood over the open bicuspid valve into the left ventricle, just as described for the right side of the heart. The bicuspid valve is closed in the same way as the tricuspid and after

[1] It is a mistake to think that the blood all accumulates in the auricle before any is forwarded to the ventricle.

a brief pause the left ventricle contracts, forcing the blood over the open semilunar valve, into the aorta. From the aorta and its branches the blood travels in the capillaries to every part of the body. The capillaries unite to form veins, and finally the blood is returned by means of the venæ cavæ to the right auricle, which completes the circuit.

The pulmonary circulation.—The lesser circulation, from the right ventricle to the left auricle, is called the pulmonary circulation.

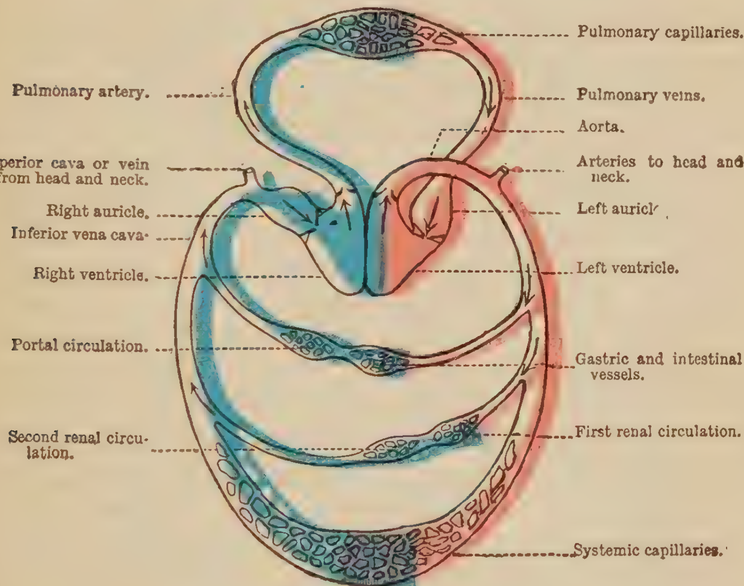


FIG. 147.—DIAGRAM OF THE CIRCULATION. (Halliburton.)

cion. The purpose of the pulmonary circulation is to carry the blood which has been through the system, giving up oxygen and collecting carbon dioxide, to the air sacs of the lungs, where the red cells are recharged with oxygen, and the carbon dioxide is reduced to the standard amount. (See page 261.)

The systemic circulation. — The more extensive circulation, from the left ventricle to all parts of the body, and the return to the right auricle, is known as the systemic circulation. The purpose of the systemic circulation is to carry oxygen and nutritive material to all parts of the body, and gather up waste products.

This double circulation, pulmonary and systemic, is constantly

and simultaneously going on, as each half of the heart is in a literal sense a force pump.

The heart as a pump. — The muscles[1] of the auricles and ventricles are so arranged that when they contract, they lessen the capacity of the chambers which they enclose. When this happens the blood from the contracting chamber is expelled in the direction of the arrows, since the valves prevent its passage in the opposite direction.

The first sign of contraction is noted in the sinus tissue of the right auricle — the sino-auricular node — which is sometimes designated as the pace-maker of the heart. From this spot the wave of contraction spreads over the muscles of both auricles. These contract simultaneously, driving the blood into the ventricles. Meanwhile the wave of contraction has passed from the auricles to the ventricles, and now spreads over the ventricles, which contract simultaneously.

The wave of contraction. — If a stimulus be applied to one end of a muscle, a wave of contraction sweeps on over the entire tissue. It is therefore easy to conceive how a wave of contraction can sweep over the muscular tissue of the auricles which is practically continuous. The question is — how is this wave transmitted to the muscular tissue of the ventricles which is *not* continuous with that of the auricles? The connecting pathway is furnished by the auriculo-ventricular bundle of His which transmits the impulses and causes the wave of contraction to spread over the ventricles. (See page 180.)

The heart-beat. — By a heart-beat we mean a coördinated contraction of the cardiac muscle resulting in the expulsion of blood from both ventricles. It consists of (1) an active phase or period of contraction called the *systole,* and (2) a passive phase or period of dilatation and rest[2] called the *diastole.* The combination of the systole and diastole constitutes a *cardiac cycle* and corresponds to the heart-beat. The heart of a man at rest may beat seventy-two times a minute. Some individuals have a lower and others a higher average. This rate may be doubled by exercise. If we assume that the heart beats 75 times a minute, the time required for a cardiac cycle is about 0.8 of a second, and half

[1] See page 174 and Fig. 106.

[2] The period of rest is now often considered separately as the diastasis or pause

of this, or 0.4 of a second, represents the diastole or passive phase.

Heart sounds and murmurs. — If the ear be applied over the heart, certain sounds are heard, which recur with great regularity. The first sound is a comparatively long, booming sound; the second, a short, sharp, sudden one. The sounds resemble the syllables *lubb dup.* The first sound is thought to be due to vibrations caused by the closure of the auriculo-ventricular valves and the contraction of the ventricles; the second is attributed to vibrations set up by the sudden closure of the semilunar valves. In certain diseases of the heart these sounds become changed and obscure, and are called murmurs. These are often due to failure of the valves to close properly, thus allowing regurgitation of the blood.

Cause of the heart-beat. — The cause of the heart-beat is still an unsettled question. We do not know whether the rhythmic contractions are due to the nerve tissue which the heart contains, or whether they are due to a power inherent in the muscle itself. The results of many experiments support the theory that the function of the nerve tissue is regulatory; that the contractions are due to the inherent power of automaticity, and that the stimulus which excites the contractions is a chemical one dependent upon the presence of definite proportions of certain salts in the blood. It has been shown that all the constituents of the blood can be dispensed with except water and these essential salts, *i.e.*, sodium chloride 0.9 per cent, calcium chloride 0.024 per cent, and potassium chloride 0.042 per cent.[1] Under normal conditions these salts are always present, and as the blood is constantly passing through the heart, it follows that the heart is subjected to a continuous stimulus. It is natural to question why the heart is not in a state of continuous contraction? In other words, how is relaxation possible? In answer it may be stated that as soon as the heart has contracted it loses its irritability to every sort of stimulus and relaxes. After a time its irritability returns and it reaches a condition in which it is again able to respond to a stimulus and contracts again. Each contraction is followed by a period of relaxation known as the *refractory period.* Thus the rhythmic action of the heart is due to the refractory period.

[1] A solution of this composition is known as Ringers' solution.

Automaticity. — The most remarkable power of cardiac muscle is its automaticity. Skeletal muscle rarely contracts except in response to the arrival of stimuli by way of the motor nerves. Visceral muscle shows an automatic tendency, but this power is most highly developed in the heart. This may be demonstrated by removing the heart of a frog from the body of the animal. The heart will continue to beat for hours provided it is kept moist with Ringers' solution. The degree of automatic power possessed by different regions of the heart varies. Some parts beat faster than others. The most rapidly contracting part is the sino-auricular node of the right auricle. It is from this particular spot that the wave of contraction radiates, and from here it is transmitted over the bundle of His to the ventricles. Ordinarily, the ventricles beat at the rate set by the right auricle, but if for any reason the auricle ceases to beat, the ventricles will beat independently but at a slower rate.[1] Thus the normal sequence of the contraction depends upon the fact that the automaticity of the right auricle is more highly developed than that of the ventricles.

Nervous control of the heart. — Although the heart contracts automatically and rhythmically, it is under normal conditions controlled by two sets of nerves. These consist of inhibitory nerves coming to the heart from the pneumogastric or vagus nerve, and accelerator nerves from the sympathetic system. The inhibitory nerves have their cell-bodies situated in the medulla where they form a cardio-inhibitory centre. The location of the cardio-accelerator centre has not been determined. Both the inhibitory and accelerator nerves are in a state of constant, though slight, activity. This means that the heart-beat is controlled by two antagonistic influences, one tending to slow the heart action, and the other to quicken it. If the inhibitory centre is stimulated to greater activity, the heart is slowed still further. If this center is inhibited, the heart-rate is increased, because the inhibitory action is removed. Stimulation of the accelerator nerves results in a quickened heart-beat, and section of these nerves slows the heart.

[1] Experimentally the bundle of His may be damaged, with the result that the auricles beat as before, but the ventricles adopt a slower rate, thus creating a condition known as heart-block.

Factors maintaining arterial circulation. — The most important factors maintaining arterial circulation are (1) the pumping action of the heart,[1] (2) the extensibility and elasticity of the arterial walls, and (3) the peripheral resistance.

The extensibility and elasticity of the arterial walls. — Each time the ventricles contract they force a certain amount of blood into arteries that are already full.[2] The extensibility of the arteries enables them to distend and receive this extra supply of blood. This period of distention corresponds to the contraction period of the heart. Just as soon as the force is removed, the elasticity of the arteries causes them to contract, and exerts such a pressure on the contained blood, that this blood is forced into the capillaries just rapidly enough to allow the arteries time to reach their usual size by the beginning of the next contraction period of the heart. They thus serve not only as conducting tubes but exert a force that assists the heart in driving the blood into the capillaries.

The extensibility and elasticity of the arteries change with the health and age of the individual. Sometimes as the result of disease, and always as we grow older, the arterial walls grow stiffer and more rigid, and become less well adapted for the unceasing work they are called upon to perform. This condition is known as arteriosclerosis.

Peripheral resistance. — This term is used to designate the resistance offered by the innumerable arterioles and capillaries into which the large arteries empty. It is easy to realize that a large tube like the aorta offers less resistance to the flow of blood, than an enormous number of microscopic tubes like the capillaries.

Factors maintaining venous circulation. — The effect of the pumping action of the heart is not entirely spent in forcing the blood through the arteries and capillaries. A little force still remains to propel the blood back to the heart again, and the presence of valves keeps it flowing in the right direction, *i.e.*, toward the heart. The return flow is also favored by (1) the suction action of the heart caused by the emptying of the auricles, (2) the heart and respiratory movements which cause continual changes of pressure in the thorax and abdomen, (3) the contractions of the

[1] See page 230.

[2] Estimated all the way from 2 to 6 ounces.

skeletal muscles which exercise a massaging action upon the veins, and aided by the valves, propel the blood toward the heart.

The velocity of the blood-flow. — In all the large arteries the blood moves rapidly; in the capillaries very slowly; and in the veins the velocity is augumented as they increase in size, but never equals that in the aorta. The underlying principle is that in any

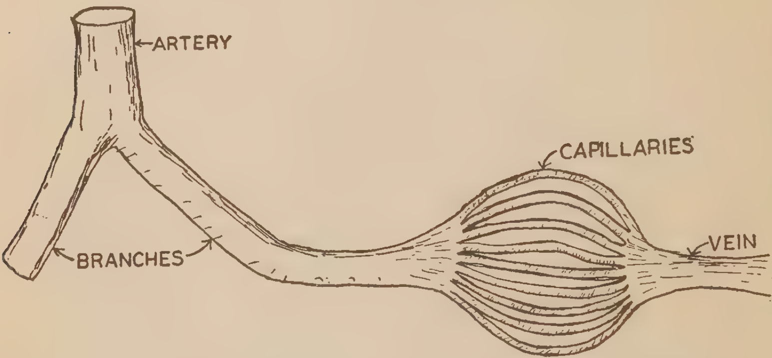


Fig. 148. — Diagram to Illustrate Variations in Velocity of Blood Flow. If a vessel divides into two branches, these will be individually of less cross-section than the main trunk, but united they will exceed it. Linear velocity will be lower in the branches than in the parent stock. The sum of the cross-sectional areas of the capillaries is greater than that of the artery or vein.

stream the velocity is greatest where the cross-section of the channel is least, and lowest where the cross-section is greatest. The application of this principle requires that we regard the aorta as the narrowest and the capillaries as the widest part of the vascular system. This is readily admitted if we remember that it is the combined channels of millions of capillaries which we have to compare with the aorta. It is a generally accepted truth that when a vessel divides, the sum of the cross-sections of the two branches is greater than that of the main trunk. Consequently the velocity will be reduced when an artery divides, and increased when two veins unite to make one. The reason why the velocity in the veins never equals that in the aorta is because the cross-section of the two venæ cavæ is greater than the cross-section of the single aorta. The actual service of the blood to the tissues is rendered in the capillaries (since the walls of the arteries and veins are too thick to permit of diffusion), hence the value of the slow passage.

Distribution of blood to different parts of the body. — The quantity of blood contained in the body is always about the same, but the distribution varies, and is determined by the needs of the different parts. When the digestive organs are active, they need an extra supply of blood, which is furnished by depleting the quantity in less active organs, *i.e.*, the muscles or skin. On the other hand, active muscular work requires that an increased supply of blood be sent to the muscles and lungs and less to the digestive organs.

BLOOD PRESSURE

By blood pressure is meant the pressure the blood exerts against the walls of the vessels in which it is contained. The term includes arterial, capillary, and venous pressure. A vein is easily flattened under the finger; an artery offers a stronger resistance. This is an indication of a great difference between arterial and venous pressure. This difference is also shown when an artery and a vein are cut; the blood springs from the artery in a pulsating spurt, while the flow from the vein is continuous and even when copious "wells up" rather than "spurts out."

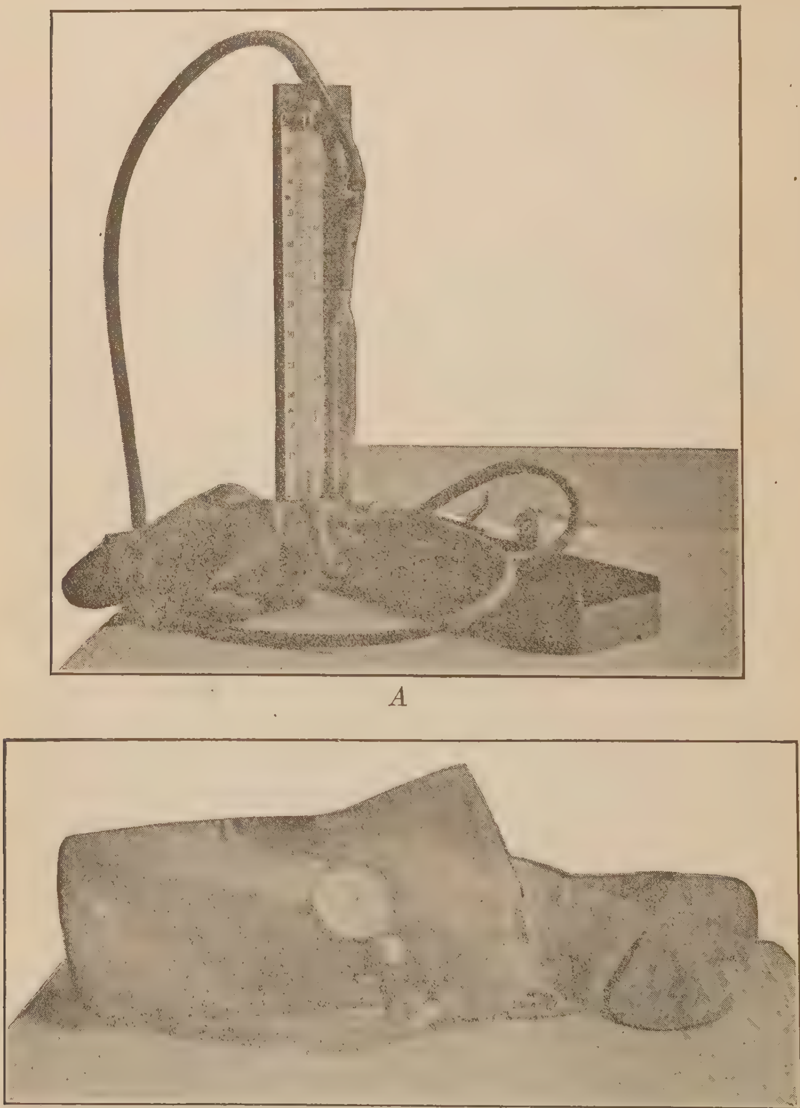
Various experiments have put us in possession of the following facts. Pressure in the arteries is high and fluctuating, slightly higher in the large trunks than in their branches; pressure in the veins is low and relatively constant. It must be higher in the small veins than in the large ones they unite to form, because the direction of the blood-flow is from the smaller to the larger ones.

When the blood leaves the left ventricle the high pressure which it exerts against the wall of the aorta may be regarded as a measure of energy. This energy is transformed into heat in overcoming the friction encountered in the vessels. When the blood reaches the capillaries, the surface is multiplied and the friction increased, This offers an impediment to the flow, and the result is a *decided drop in the pressure.*

Arterial pressure is not uniform, but varies (1) with the systole and diastole of the heart, being greater during the systole; (2) it is less in youth, and increases as we grow older, because the arteries are less elastic; (3) conditions of health may affect the normal muscular tone of the arteries and heart. When the arteries lose their tone, or the heart-beat loses its force, the blood pressure is

low. When the arteries are overconstricted, or the heart overstimulated, the blood pressure is high.

Method of determining blood pressure. — It is customary to try the pulse at the wrist to determine whether the patient has



A

B

FIG. 149. — SPHYGMOMANOMETERS. *A*, the mercury instrument is accurate, although a trifle more bulky than the spring type. *B*, the spring type of instrument.

high blood pressure. If the radial artery is hard and incompressible it may indicate either that some change has occurred in the vessel, or that the pressure is high. If, however, the pulse is easy to obliterate with the fingers it is usual to find a low pressure.

Of late years many forms of apparatus have been devised by which a more accurate knowledge of this condition can be obtained. This apparatus is called a sphygmomanometer, and consists of a scaled column of mercury which is connected with an air bag by rubber tubing. The air bag is in turn connected with a small hand pump and is contained in a cuff of either leather or cloth. Some instruments are constructed with a spring scale instead of a column of mercury but the principle is the same.

The air bag contained in the cuff is buckled snugly about the arm just above the elbow so as to compress the brachial artery. By placing the finger upon the pulse at the wrist (as we inflate the bag), we finally reach a point where the pulse disappears, or in other words, the pressure in the bag as indicated on the instrument is equal to the pressure, which is necessary to overcome the pressure of the artery wall, plus the force of the heart-beat. This is known as systolic pressure. Another method is to place a stethoscope over the brachial artery (instead of the hand on the pulse), and note the point at which the pulse disappears. After the systolic pressure has been ascertained by releasing the air slightly in the cuff and allowing the scale to drop, the pulse first becomes more positive and then fainter until it is lost to the stethoscope. The point lowest on the scale where it disappears is known as the diastolic pressure. The diastolic pressure cannot be taken by the finger-pulse method. It is necessary to use a stethoscope.

Normal degree of blood pressure. — The normal degree of blood pressure necessary to obliterate the pulse in the brachial artery is about 11 to 13.5 cm. (centimetres of mercury column) for systolic, and 5.5 to 7 cm. diastolic. Pressure varies with age, and even in health is not constantly the same. Increase in the force and frequency of the heart increases the pressure. Cold, drugs, etc. which constrict the arterial pulse may raise the blood pressure. Heat, and the drugs of the vaso-dilator group like nitroglycerin, may lower it.

THE PULSE

When the finger is placed on an artery, a sense of resistance is felt, and this resistance seems to be increased at intervals, corresponding to the heart-beat, the wall of the artery at each heartbeat being felt to rise up or dilate under the finger. This alternate dilatation and contraction of the artery constitutes the pulse; and in certain arteries which lie near the surface this pulse may be seen with the eye. When the finger is placed on a vein, very little resistance is felt; and, under ordinary circumstances, no pulse can be perceived by the touch or by the eye.

As each expansion of an artery is produced by a contraction of the heart, the pulse, as felt in any superficial artery, is a convenient guide for ascertaining the character of the heart's action.

Locations where the pulse may be felt. — The pulse may be counted wherever an artery approaches the surface of the body. These locations are: —

(1) The *facial* artery, where it passes over the lower jawbone.

(2) The *temporal* artery, above and to the outer side of the outer canthus of the eye.

(3) The *brachial* artery, along the inner side of the biceps muscle.

(4) The *radial* artery, on the thumb side of the wrist. On account of its accessible situation the radial artery is usually employed for this purpose.

(5) The *femoral* artery, where it passes over the pelvic bone.

(6) The *dorsalis pedis*, on the dorsum of the foot.

Points to note in feeling a pulse. — In feeling a pulse the following points should be noted.

(1) *Frequency*, or the number of pulse-beats per minute.

(2) *Strength*, or the force of the heart-beat.

(3) *Regularity*, or the same number of beats per minute.

(4) *Equality.* — Each beat should have the same force, not some strong and some weak. It sometimes happens that a beat is missed because the heart-beat is too weak to distend the artery. This is called an *intermittent* pulse.

Occasionally there is a lack of tone in the arterial walls and a *dicrotic* pulse is felt. This means that the pulsations are divided and the second part of the beat is weaker than the first.

(5) *Blood pressure.* — This is suggested by the amount of force that is required to obliterate the pulse.

Average frequency of the pulse. — The average frequency of the pulse in man is seventy-two beats per minute. This rate may be increased after eating or by muscular action. Even the variation of the muscular effort entailed between the standing, sitting, and recumbent positions will make a difference in the frequency of the pulse of from eight to ten beats per minute. Mental excitement may also produce a temporary acceleration, varying in degree with the peculiarities of the individual. Age has a marked influence. At *birth* the pulse rate is about *130* per minute; at three years, *100;* in adult life, *72;* in old age, *65.* It is somewhat more rapid in women than in men and is lowered during sleep. Idiosyncrasies are frequently met with. A person in perfect health may have a much higher or a much lower rate than 72. The relative frequency of the pulse and respirations is about four heart-beats to one respiration.

As a rule, the rapidity of the heart's action is in inverse ratio to its force. An infrequent pulse, within physiological limits, is usually a strong one, and a frequent pulse comparatively feeble; the pulse in fever or debilitating affections becoming weaker as it grows more rapid.

LYMPH

Formation of lymph. — The lymph is derived from the blood in the capillaries, but the exact process is still an open question. It is considered probable that it is partly a process of filtration which depends on the permeable nature of the walls of the capillaries, and partly the result of a secretory process on the part of the endothelial cells lining the capillaries. The filtration theory is supported by the fact that the blood in the capillaries is under greater pressure than in the arteries or veins. The secretory process is supported by the chemical differences between the blood and the lymph.

Factors controlling the flow of lymph. — The onward progress of the lymph from the tissues to the veins is maintained chiefly by three things.

(1) **Differences in pressure.** — The lymph in the tissue spaces is under greater pressure than the lymph in the lymph capillaries,

and the pressure in the larger lymphatics near the ducts is much less than in the smaller vessels. Consequently we may consider that the lymphatics form a system of vessels leading from a region of high pressure, viz. the lymph spaces of the tissues, to a region of low pressure, viz. the interior of the large veins of the neck.

(2) **Muscular movements and valves.** — The muscular movements of the body compress the lymphatics and force the lymph on in the proper direction. The numerous valves prevent a return flow in the wrong direction.

(3) **Respiration.** — During each inspiration the pressure on the thoracic duct is less than on the lymphatics outside the thorax, and the lymph is accordingly "sucked" into the duct. During the succeeding expiration the pressure on the thoracic duct is increased, and some of its contents, prevented by the valve from escaping below, are pressed out into the innominate veins.

Œdema. — The lymph in the various lymph spaces of the body varies in amount from time to time, but under normal circumstances never exceeds certain limits. Under abnormal conditions, these limits may be exceeded, and the result is known as œdema, or dropsy. Similar excessive accumulations may also occur in the larger lymph spaces, the serous cavities.

Among the possible causes of œdema are: —

(1) An excessive formation, the lymph gathering in the lymph spaces faster than it can be carried away by a normal flow.

(2) Any obstruction to the flow of lymph from the lymph spaces.

FŒTAL CIRCULATION

Certain structures are necessary to the performance of fœtal circulation, but are of no use after birth. They are as follows: —

(1) **Foramen ovale.** — An opening between the two auricles. It furnishes direct communication between them.

(2) **Ductus arteriosus.** — A blood-vessel connecting the aorta and pulmonary artery.

(3) **Ductus venosus.** — A blood-vessel connecting the umbilical vein and the inferior vena cava.

(4) **The placenta and umbilical cord.** — The placenta is a mass of tissue rich in blood-vessels which is in close contact

with the lining of the uterus. The umbilical cord unites the placenta with the navel of the child. The cord is made up of two arteries and one large vein protected by Wharton's jelly. The arteries are branches of the arterial system of the fœtus, and carry blood from the fœtus to the placenta where it is separated by the thinnest of walls from the maternal blood in the blood-vessels of the uterus. The usual distinctions between arterial and venous blood cannot be recognized, as the blood of the fœtus is never up to the arterial standard of the mother. The best blood is that which has been improved by effecting exchanges with the blood in the uterine vessels, and is carried from the placenta to the fœtus by the vein. By means of the placenta the fœtus obtains oxygen, but it is more than a lung; it is the seat

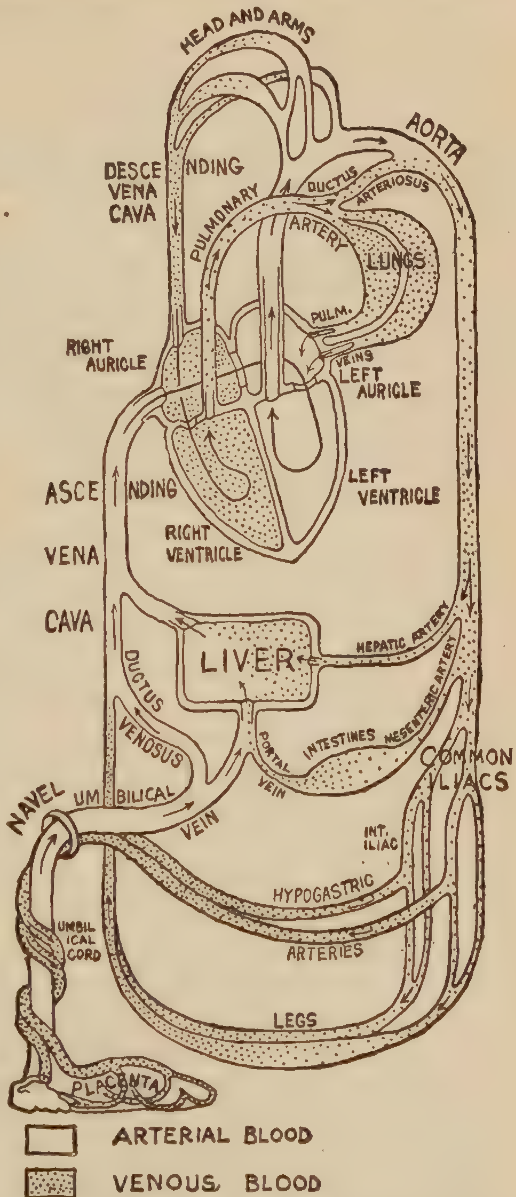


FIG. 150. — DIAGRAM OF CIRCULATION BEFORE BIRTH. Fœtal type. The arrows indicate the course of the blood. (Cooke.)

of the absorption of food, and serves for the unloading of wastes.

Course of the blood. — The blood is carried from the placenta along the umbilical cord by the umbilical vein. Entering the fœtus it is conveyed into the ascending vena cava partly through the liver but chiefly through the ductus venosus, which connects these two vessels. From the ascending vena cava it enters the right auricle, passes through the foramen ovale into the left auricle, thence into the left ventricle, and out through the aorta, which distributes it principally to the upper extremities. The blood from the head and upper extremities returns by the descending vena cava to the right auricle, then passes into the right ventricle, and out through the pulmonary artery to the lungs. As the lungs in the fœtus are solid, they require very little blood (only for nutrition), and the greater part of the blood passes through the ductus arteriosus into the descending aorta, where, mixing with the blood delivered to the aorta by the left ventricle, it descends to supply the lower extremities of the fœtus. The chief portion of this blood is carried to the placenta by the two umbilical arteries, but a small amount passes back into the ascending vena cava and mixes with the blood from the placenta.

From this description of the fœtal circulation, it follows: —

1. That the placenta serves the purpose of a respiratory, nutritive, and excretory organ.

2. That the liver receives blood directly from the placenta; hence the large size of this organ at birth.

3. That the blood from the placenta passes almost directly into the arch of the aorta, and is distributed by its branches to the head and upper extremities; hence the large size and perfect development of these parts at birth.

4. That the blood in the descending aorta is chiefly derived from that which has already circulated in the upper extremities, and, mixed with only a small quantity from the left ventricle, is distributed to the lower extremities; hence the small size and imperfect development of these parts at birth.

Changes in the vascular system at birth. — From the foregoing description it is obvious that at birth very important changes must take place: —

1. The blood clots in the umbilical vein, between the usual

ligature and the liver, also in the ductus venosus. The blood clot becomes organized and these two vessels become obliterated.

2. As respiration commences, the blood traverses the pulmonary arteries, and then returns to the heart by the pulmonary veins; this raises the blood pressure in the left auricle, and causes the valve over the foramen ovale to close.

3. The blood in the ductus arteriosus clots, the clot organizes, and the ductus arteriosus becomes a fibrous cord.

4. The blood in the hypogastric arteries also clots, the clots organize, and these vessels become obliterated.

Occasionally some of the embryonic by-passes fail to close, and so much venous blood enters the arterial system that a *blue baby* is the result. In such instances the child suffers from malnutrition and the chances for survival are slight.

SUMMARY

- **General Circulation**
  - **Pulmonary Circulation**
    - Right auricle to right ventricle, then pulmonary arteries to lungs. Capillary system. Return by pulmonary veins to left auricle.
    - **Purpose** — To increase oxygen and decrease carbon dioxide to standard amount.
  - **Systemic Circulation**
    - Left auricle to left ventricle, then by means of aorta and its branches to all parts of the body. Capillary system. Return by veins which empty into superior and inferior venæ cavæ.
    - **Purpose**
      - Carry, and give up to the cells
        - Oxygen.
        - Nutritive materials.
      - Take from the cells
        - Carbon dioxide.
        - Waste products.
- **Heart**
  - **Pumping Action**
    - Muscles contract and lessen capacity of auricles and ventricles, thus forcing blood into arteries.
  - **Wave of Contraction**
    - Starts at sino-auricular node, transmitted to bundle of His, which in turn transmits it to the ventricles.
  - **Heart Beat**
    - Coördinated contraction of cardiac muscle.
    - **Systole** — Active stage; **Diastole** — Passive stage
      - Cardiac cycle, 72 per minute.
      - Occupies about 0.8 of a second.
    - Cause
      - Automaticity inherent in heart muscle.
      - Stimulated by chlorides
        - Sodium.
        - Potassium.
        - Calcium.
      - Innervation is regulatory.
        - Vagus nerve — inhibitory.
        - Sympathetic system — accelerator.
  - **Heart Sounds**
    - Lubb
      - Vibrations caused by closure of auriculo-ventricular valves and the contraction of ventricles.
    - Dup — Vibrations caused by closure of semilunar valves.
- **Factors Maintaining Arterial Circulation**
  1. Pumping action of the heart.
  2. The extensibility and elasticity of the arterial walls.
  3. Peripheral resistance.

Factors Maintaining Venous Circulation
1. Some force due to pumping action of the heart.
2. Suction action of the heart.
3. Changes of pressure in thorax and abdomen due to heart and respiratory movements.
4. Contractions of the skeletal muscles.

Velocity of Blood-flow
- Arteries — blood moves rapidly in large arteries, more slowly in smaller ones.
- Capillaries — blood moves very slowly.
- Veins — blood moves slowly in small veins, more rapidly in larger veins, but never as rapidly as in arteries.

Blood Pressure
- Pressure blood exerts against walls of vessels.
- Arterial
  - High and fluctuating.
  - Not uniform
    1. Higher during systole.
    2. Lower during diastole.
    3. Increases with age.
    4. Decreases if heart or arteries lose their tone.
- Venous — Low and constant.
- Determined by use of sphygmomanometer
  1. Scaled column of mercury connected with air bag.
  2. An air bag contained in a cuff of leather or cloth.
  3. Air bag also connected with hand pump.
- Normal
  - Systolic or maximum — 11.0 to 13.5 cm.
  - Diastolic or minimum — 5.5 to 7.0 cm.

Pulse . . .
- Alternate contraction and expansion of artery.
- **Locations where Pulse may be Counted**
  - Facial artery.
  - Temporal artery.
  - Brachial artery.
  - Radial artery.
  - Femoral artery.
  - Dorsalis pedis.
- **Points to Note**
  - Frequency.
  - Strength.
  - Regularity.
  - Equality.
  - Blood pressure.
- **Pulse Rate** (Higher in women than in men.)
  - Infant, 130
  - Three years, 100
  - Adult, 72
  - Old age, 65

- **Pulse**
  - **Changes in Pulse Rate may be Due to**
    - Eating.
    - Muscular activity.
    - Mental excitement.
    - Age.
    - Sleep.
    - Condition of health.
    - Idiosyncrasies.
- **Lymph**
  - **Formation**
    - Process of filtration.
    - Process of secretion.
  - **Factors Controlling Flow**
    - Differences in pressure.
    - Muscular movements and valves.
    - Respiration.
- **Œdema**
  - Accumulation of lymph in tissues.
  - May be caused by
    1. Excessive formation.
    2. Obstruction to flow of lymph from tissue.
- **Fœtal Circulation**
  1. Direct communication between right and left auricle by means of foramen ovale.
  2. Direct communication between umbilical vein and inferior vena cava. Ductus venosus.
  3. Direct communication between pulmonary artery and aorta. Ductus arteriosus.
  4. Oxygen and nutritive substances obtained from placenta.
- **Changes in Vascular System at Birth**
  1. Umbilical vein and ductus venosus become obliterated.
  2. Respiration stimulates pulmonary circulation; this raises the blood pressure in left auricle, and closes foramen ovale.
  3. Ductus arteriosus becomes a fibrous cord.
  4. Hypogastric arteries become obliterated.

CHAPTER XIII

RESPIRATORY SYSTEM: NOSE; LARYNX; TRACHEA; BRONCHI; LUNGS. — RESPIRATION; ABNORMAL TYPES OF RESPIRATION. MODIFIED RESPIRATORY MOVEMENTS

THE process of respiration is dependent upon the proper functioning of certain organs, which we group together and call a respiratory system. The essentials of a respiratory system consist of a moist and permeable membrane, with a moving stream of

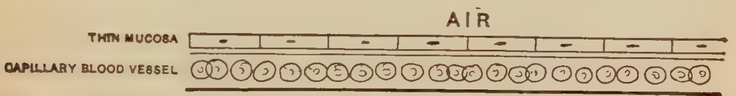


FIG. 151. — DIAGRAM OF THE ESSENTIALS OF A RESPIRATORY SYSTEM. (Gerrish.)

blood containing a high percentage of carbon dioxide on one side, and air or fluid containing a high percentage of oxygen on the other. In most aquatic animals the respiratory organs are external in the form of gills; in terrestrial, or air-breathing animals, the respiratory organs are situated internally in the form of lungs, and are placed in communication with the nose and mouth by means of the bronchi, trachea, and larynx.

NOSE

The nose is the special organ of the sense of smell, but it also serves as a passageway for the entrance of air to the respiratory organs. It consists of two parts, — the external feature, the nose, and the internal cavities, the nasal fossæ.

The external nose is composed of a triangular framework of bone and cartilage, covered by skin and lined by mucous membrane. On its under surface are two oval-shaped openings — the nostrils, which are the external openings of the nasal fossæ. The margins of the nostrils are provided with a number of stiff hairs, which ar-

rest the passage of dust and other foreign substances which might otherwise be carried in with the inspired air.

The nasal fossæ are two irregularly wedge-shaped cavities, separated from one another by a partition, or septum. The septum is formed partly by the vertical plate of the ethmoid, partly by the vomer, and partly by cartilage. Figure 152 shows the portions formed by the ethmoid, vomer, and cartilage.

The turbinated bones and turbinated processes of the ethmoid, which are exceedingly light and spongy, project into the nasal cavities, and divide them into three incomplete passages from before backwards, — the superior, middle, and inferior meatus. The palate and maxillæ separate the nasal and mouth cavities, and the horizontal plate of the ethmoid forms the partition between the cranial and nasal cavities.

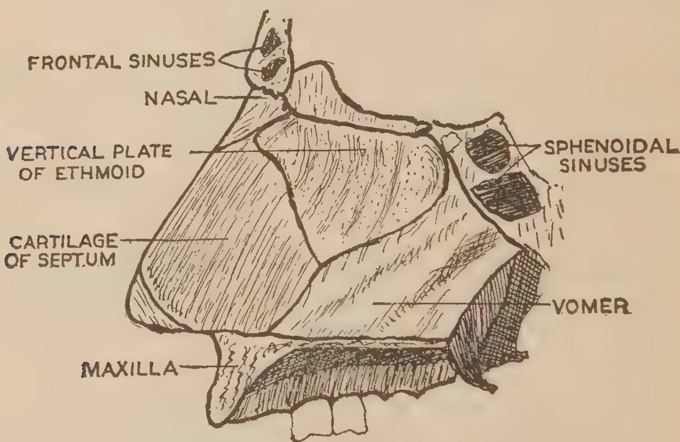


FIG. 152. — BONES AND CARTILAGE FORMING SEPTUM OF NOSE.

These cavities [1] communicate with the air in front by the anterior nares, or nostrils, while behind they open into the back of the pharynx by the two posterior nares. They are lined with mucous membrane [2] which is continuous externally with the skin, and internally with the mucous membrane lining the passages and

[1] Eleven bones enter into the formation of the nasal cavities: the floor is formed by the palate (2) and part of the maxillæ bones (2); the roof is chiefly formed by the horizontal plate of the ethmoid bone (1), the sphenoid (1), and by the (2) small nasal bones; in the outer walls we find, in addition to processes from other bones, the two scroll-like turbinated bones (2). The vomer (1) forms part of the septum.

[2] It is known as the pituitary or Schneiderian membrane.

sinuses shown in Fig. 97. Inflammatory conditions of the nasal mucous membrane may extend into the sinuses.

Advantages of nasal breathing. — Under normal conditions breathing should take place through the nose only (1) because the arrangement of the turbinated bones makes the upper part of the

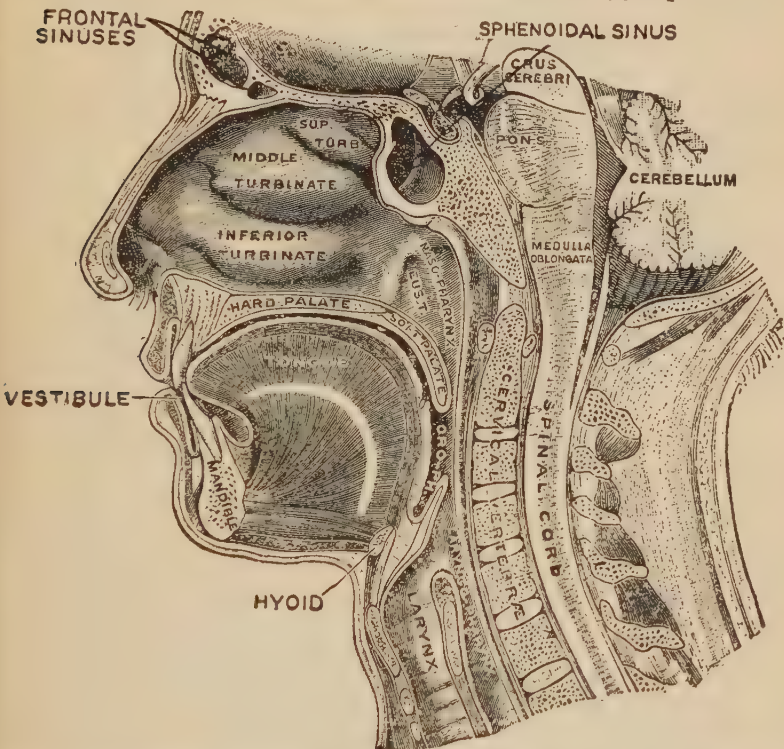


FIG. 153. — SAGITTAL SECTION OF THE FACE AND NECK, SHOWING THE FIRST PORTIONS OF THE ALIMENTARY AND RESPIRATORY TRACTS. (Gerrish.)

nasal passages very narrow; (2) these passages are thickly lined, and freely supplied with blood-vessels, so that they can, even in the very coldest weather, moisten and warm the air before it reaches the lungs; and (3) the presence of hairs at the entrance to the nostrils serves as filters.

Mouth and pharynx. — The mouth serves as a passageway for the entrance of air, and the pharynx transmits the air from the nose or mouth to the larynx, but both are more closely associated with digestion than respiration, and will be described with the digestive organs.

RESPIRATORY SYSTEM

Under this heading we group the organs which are concerned in the process of respiration. In man they are as follows: —

1. Larynx.
2. Trachea.
3. Bronchi.
4. Lungs.

THE LARYNX

The larynx, or organ of voice, is placed in the upper and front part of the neck, between the base of the tongue and the top of the trachea. Above and behind lies the pharynx, which opens into the œsophagus, or gullet, and on either side of it lie the great vessels of the neck. The larynx is broad above and shaped somewhat like a triangular box, with flat sides and prominent ridge in front. Below it is narrow and rounded where it blends with the trachea. It is made up of nine pieces of fibro-cartilage, united by elastic ligaments, and moved by numerous muscles.

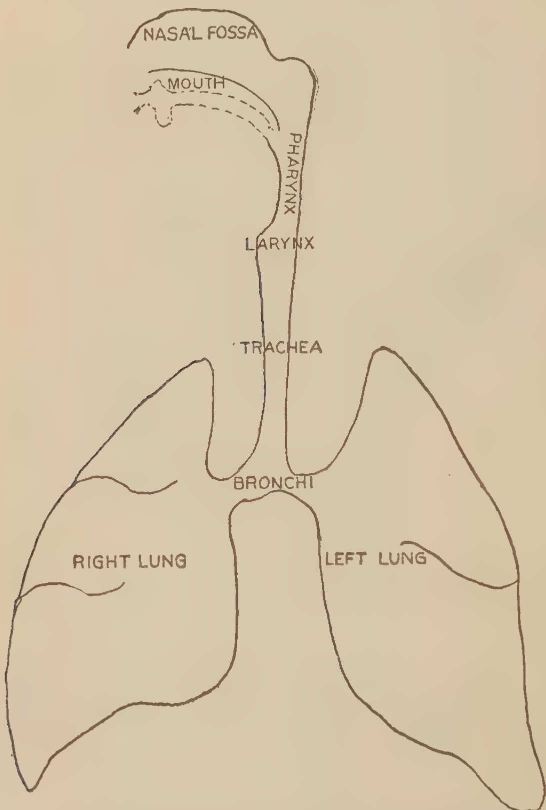


Fig. 154. — Diagram of the Respiratory System.

The three principal cartilages are the **cricoid**, **thyroid**, and **epiglottis**. The cricoid resembles a seal ring with the hoop part in front and the signet part in the back. The thyroid resembles

a shield and is the largest. It rests upon the cricoid and consists of two square plates, or alæ (right and left), which are joined in front and form by their union the laryngeal prominence, called Adam's apple. The epiglottis is shaped like a leaf. The stem is inserted in the notch between the two plates of the

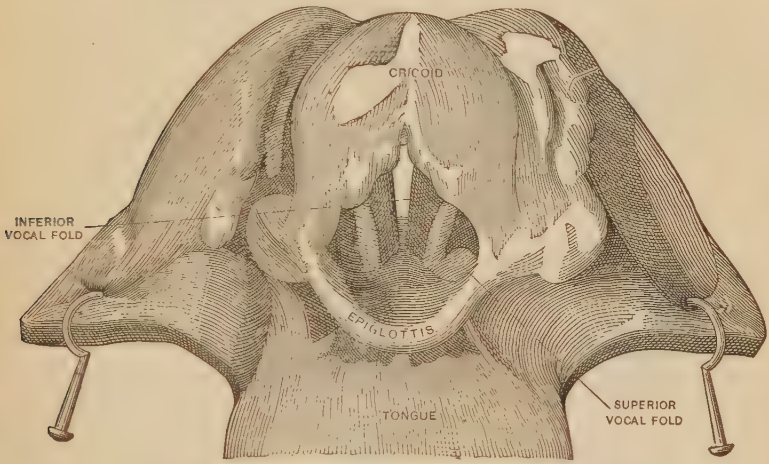


Fig. 155. — Larynx. Viewed from above. (Gerrish.)

thyroid. The larynx is lined throughout by mucous membrane, which is continuous above with that lining the pharynx, and below with that lining the trachea.

The glottis. — Across the middle of the larynx is a transverse partition, formed by two folds of the lining mucous membrane, stretching from side to side, but not quite meeting in the middle line. They thus leave in the middle line a chink, or slit, running from front to back, called the *glottis*, which is the narrowest segment of the air passages. The glottis is protected by the leaf-shaped lid of fibro-cartilage, called the epiglottis, which shuts down upon the opening during the passage of food or other matter into the œsophagus.

The vocal cords. — Embedded in the mucous membrane at the edges of the slit are fibrous and elastic ligaments, which strengthen the edges of the glottis and give them elasticity. These ligamentous bands, covered with mucous membrane, are firmly attached at either end to the cartilages of the larynx, and are called the *true vocal cords,* because they function in the production of the

voice. Above the true vocal cords are two *false vocal cords*, so called because they do not function in the production of the voice.

Variations in size of glottis. — The glottis varies in shape and size, according to the action of the muscles upon the laryngeal walls. When the larynx is at rest during quiet breathing, the glottis is V-shaped; during a deep inspiration it becomes almost round, while during the production of a high note the edges of the folds approximate so closely as to leave scarcely any opening at all.

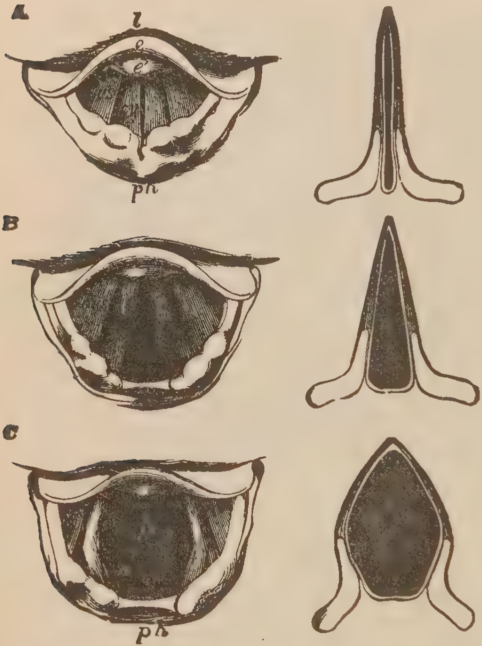


FIG. 156. — THE LARYNX AS SEEN BY MEANS OF THE LARYNGOSCOPE IN DIFFERENT CONDITIONS OF THE GLOTTIS. *A*, while singing a high note; *B*, in quiet breathing; *C*, during a deep inspiration. *l*, base of tongue; *e*, upper free edge of epiglottis; *e'*, cushion of the epiglottis; *ph*, part of anterior wall of pharynx; *cv*, the true vocal folds; *cvs*, the false vocal folds; *tr*, the trachea with its rings.

Voice. — The vocal cords produce the voice. A blast of air, driven by an expiratory movement out of the lungs, throws the two elastic cords into vibrations. These impart their vibrations to the column of air above them, and so give rise to the sound which we call the voice. The pharynx, mouth, and nasal cavities above the glottis act as resonating cavities, and by alterations in their shape and size, they are able to pick out and emphasize certain parts of the tones produced in the larynx.

Differences between male and female voice. — At puberty in the male, the larynx enlarges, giving rise to what is commonly called Adam's apple. The increase in the size of the larynx causes an increase in the length of the vocal cords. To this is due the lower pitch of the voice in the male.

THE TRACHEA

The trachea, or windpipe, is a fibrous and muscular tube, about four and a half inches (11.2 cm.) in length, and three-quar-

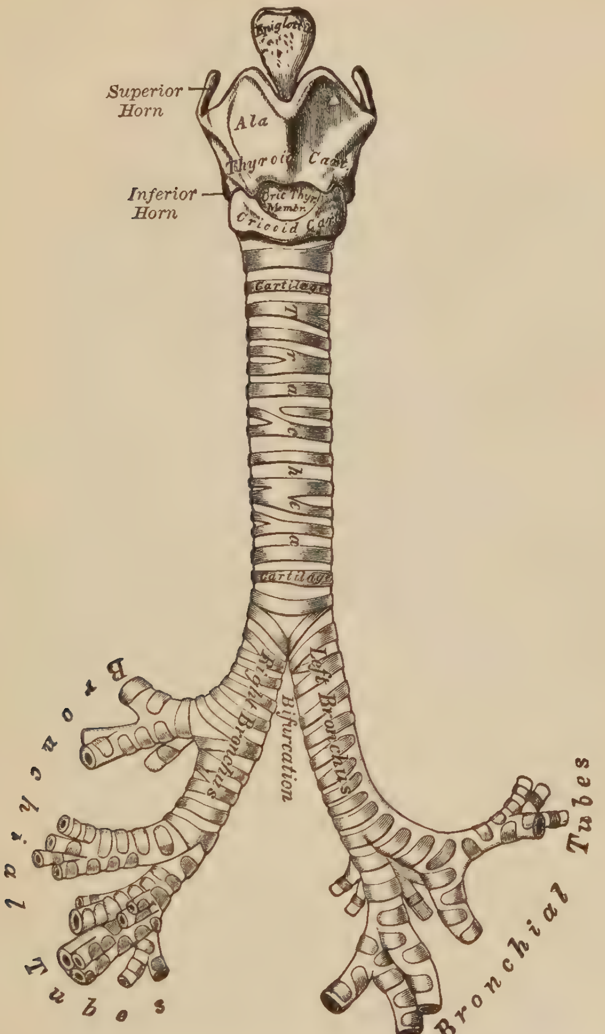


FIG. 157. — FRONT VIEW OF CARTILAGES OF LARYNX. Trachea and Bronchi.

ters of an inch (1.9 cm.) from side to side. It lies in front of the œsophagus and extends from the larynx on the level of the sixth cervical vertebra, to opposite the fourth or fifth thoracic vertebra,

where it divides into two tubes, — the two bronchi, — one for each lung.

The walls are strengthened and rendered more rigid by hoops of cartilage embedded in the fibrous tissue. These hoops are C-shaped and incomplete behind, the cartilaginous rings being completed by bands of plain muscular tissue where the trachea comes in contact with the œsophagus. Like the larynx, it is lined by mucous membrane, and has a ciliated epithelium upon its inner surface. The mucous membrane, which also extends into the bronchial tubes, keeps the internal surface of the air-passages free from impurities; the sticky mucus entangles particles of dust and other matters breathed in with the air, and the incessant movements of the cilia continually sweep this dirt-laden mucus upward and outward.

THE BRONCHI

The two bronchi, into which the trachea divides, differ slightly; the right bronchus is shorter, wider, and more nearly horizontal, the left bronchus is longer, narrower, and more nearly vertical. They enter the right and left lung, respectively, and then break up into a great number of smaller branches which are called the bronchial tubes, or bronchioles. The two bronchi resemble the trachea in structure; but as the bronchial tubes divide and subdivide their walls become thinner, the small plates of cartilage cease, the fibrous tissue disappears, and the finer tubes are composed of only a thin layer of muscular and elastic tissue lined by mucous membrane.

LUNGS

The lungs are cone-shaped organs which occupy almost all of the cavity of the thorax that is not taken up by the heart, the large blood-vessels, the lymphatics, and the œsophagus. Each lung presents an outer surface which is convex, a base which is concave to fit over the convex portion of the diaphragm, and a summit or apex which rises half an inch above the clavicle. On the inner surface is a vertical notch called the **hilum**, which gives passage to the bronchi, blood-vessels, lymph-vessels, and nerves.

The **right lung** is the larger and heavier; it is broader than the left, owing to the inclination of the heart to the left side; it is

also shorter by one inch, in consequence of the diaphragm rising higher on the right side to accommodate the liver. The right lung is divided by fissures into three lobes, upper, middle, and lower.

The **left lung** is smaller, narrower, and longer than the right. It is divided into two lobes, upper and lower. The front border is deeply notched to accommodate the heart.

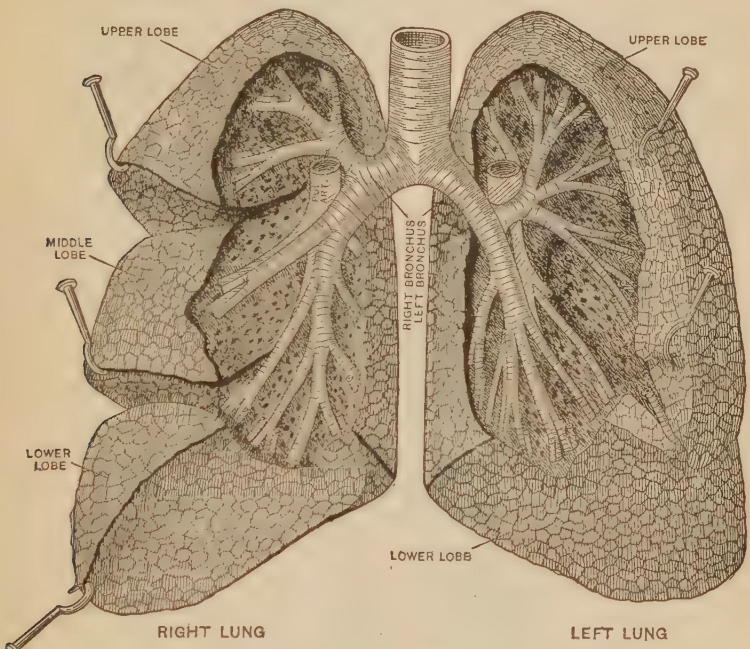


FIG. 158. — BRONCHI AND BRONCHIOLES. The lungs have been widely separated and tissue cut away to expose the air-tubes. (Gerrish.)

Anatomy of the lungs. — The lungs are hollow, rather spongy organs, and consist of the bronchial tubes and their terminal dilatations, numerous blood-vessels, lymphatics, nerves, and an abundance of fine, elastic connective tissue, binding all together. (See Fig. 107.) Each lobe of the lung is composed of many lobules, and into each lobule a bronchiole enters and terminates in an enlargement having more or less the shape of a funnel, and called an *infundibulum*. From each infundibulum there is a series of small sac-like projections known as *alveoli*, the walls of which are honeycombed with cavities called the air-cells. In this way the amount

FIG. 159. — DIAGRAM OF A LOBULE OF THE LUNG. A bronchiole is seen dividing into two branches, one of which runs upward and ends in the lobule. In the lobule are four groups of infundibula. At the left are two infundibula, the alveoli of which present their outer surfaces. Next are three infundibula in vertical section, the alveoli of each opening into the common passageway. In the next group the first infundibulum shows a pulmonary arteriole surrounding the opening of each alveolus, and the second gives the same with the addition of the close capillary network in the wall of each alveolus. Around the fourth group is a deep deposit of pigment, such as occurs in old age, and in the lungs of those who inhale coal dust and the like. On the bronchiole lies a branch of the pulmonary artery (blue), bringing blood to the infundibula for aëration. Beginning between the infundibula are the radicles of the pulmonary vein (red), a root of which lies upon the bronchiole. The bronchial artery is shown as a small vessel bringing nutrient blood to the bronchiole. (Gerrish.)

of surface exposed to the air and covered by the capillaries is so immensely increased that it is estimated the entire inner surface of the lungs is one hundred times greater than the skin surface of the body.[1]

Blood-vessels of the lungs. — Two sets of vessels are distributed to the lungs: (1) the branches of the pulmonary artery, and (2) the branches of the bronchial arteries.

(1) The branches of the pulmonary artery accompany the bronchial tubes and form a plexus of capillaries around the alveoli. The walls of the bronchioles consist of a single layer of flattened epithelioid cells, surrounded by a fine, elastic connective tissue, and are exceedingly thin and delicate. Immediately beneath the layer of flat cells, and lodged in the elastic connective tissue, is this very close plexus of capillary blood-vessels; and the air reaching the alveoli by the bronchial tubes is separated from the blood in the capillaries only by the thin membranes forming their respective walls. The pulmonary veins begin at the margin of the alveoli and return the blood distributed by the pulmonary artery.

(2) The branches of the bronchial arteries supply blood to the lung substance, — the bronchial tubes, coats of the blood-vessels, the lymph nodes, and the pleura. The bronchial veins return the blood distributed by the bronchial arteries.

Pleura. — Each lung is enclosed in a serous sac, the pleura, one layer of which is closely adherent to the walls of the chest and diaphragm (parietal); the other closely covers the lung (visceral). The two layers of the pleural sacs, moistened by serum, are normally in close contact; they move easily upon one another, and prevent the friction that would otherwise occur between the lungs and the walls of the chest with every respiration. Inflammation of the pleura is called pleurisy.

Mediastinum. — The mediastinum is the space left in the median portion of the thorax between the pleural sacs. It extends from the sternum to the spinal column, and contains a portion of many organs, *i.e.*, the trachea, œsophagus, great vessels connected with the heart, lymph-nodes, thoracic duct, and various nerves.

[1] It is estimated that the amount of lung surface which is exposed to the air is 90 square metres and the average skin surface is estimated to be $\frac{9}{10}$ of one square metre.

RESPIRATION

The main purpose of respiration is to supply all the cells of the body with oxygen and rid them of the excess carbon dioxide which results from oxidation. It also helps to equalize the temperature of the body and get rid of excess water. To accomplish these purposes three processes are necessary: —

(1) *Breathing.* — The process of breathing may be subdivided into inspiration or breathing in, and expiration or breathing out. Inspiration is a preliminary process whereby air is introduced into the lungs. Expiration is the process by which air is expelled from the lungs. This air has given up about one-fourth of its oxygen and increased the quantity of carbon dioxide one hundred times. (See page 263.)

(2) *External respiration.* — This includes two processes: (*a*) external oxygen supply or the passage of oxygen from the alveoli of the lungs to the blood; and (*b*) external carbon dioxide elimination or the passage of carbon dioxide from the blood into the alveoli of the lungs.

(3) *Internal respiration.* — This also includes two processes: (*a*) internal oxygen supply or the passage of oxygen from the blood to the cells of the tissues; and (*b*) internal carbon dioxide elimination or the passage of carbon dioxide from the cells of the tissues to the blood.

It is evident that external respiration is a process that takes place in the lungs and that internal respiration is a process that takes place in all the cells that make up the tissues of the body.

Mechanism of inspiration and expiration. — During inspiration the cavity of the chest is enlarged in all three diameters: (1) antero-posterior, (2) lateral, and (3) vertical. This is brought about by the action of the intercostal and other muscles, which elevate the ribs and thereby increase the antero-posterior and lateral diameters. The descent of the diaphragm increases the vertical diameter. The lungs are expanded exactly in proportion as the cavity enlarges. The expansion affects chiefly the elastic sacs or alveoli, and air presses into them as into a widening bellows. The atmospheric pressure outside the body is greater than the pressure within the alveoli, and this forces the air in. Upon the relaxation of the inspiratory muscles, the elasticity of the lungs,

and the weight and elasticity of the chest walls, cause the chest to return to its original size, in consequence of which the air is expelled from the lungs. As in the heart, the auricular systole, the ventricular systole, and then a pause, follow in regular order; so in the lungs the inspiration, the expiration, and then a pause, succeed one another.

Control of respiration. — Respiration is both a voluntary and an involuntary act. It is possible for a short time to increase or decrease the rate of respiration within certain limits by voluntary effort, but this cannot be done continuously. If we intentionally arrest the breathing or diminish its frequency, after a short time the nervous impulse becomes too strong to be controlled, and the movements will recommence, as usual. If, on the other hand, we purposely accelerate respiration to any great degree, the exertion soon becomes too fatiguing for continuance, and the movements return to their normal standard.

Cause of respiration. — Unlike the beat of the heart the contractions of the respiratory muscles are entirely dependent on the nervous system, especially that part known as the *respiratory centre*, which is located in the medulla oblongata.[1] Efferent nerves from the respiratory centre travel down the spinal cord and end at different levels, where they connect with the fibres of the vagi and sympathetic nerves that are distributed in the lung tissue. Afferent nerves lead from these different levels to the respiratory centre.

The consensus of opinion at the present time seems to be that the action of the respiratory centre is automatic, but that the rate and rhythm of the respiratory movements are controlled (1) by the vagi nerves, and (2) by the chemical condition of the blood.

(1) The fibres from the vagi are of two kinds: (*a*) inspiratory fibres which tend to increase the rate of respiration, and (*b*) expiratory fibres which check the action of the inspiratory set. The inspiratory fibres are stimulated to action when the lung collapses; the expiratory when the lung expands.

(2) The respiratory centre shows a specific irritability for carbon

[1] It is important to remember the difference between the heart action and respiration: the heart beats of itself, and the respiratory muscles are thrown into contraction by the brain.

dioxide, and an increased amount of carbon dioxide in the blood acts as a stimulus, increasing the rate and depth of the respirations, so that the lungs are more thoroughly ventilated. Increased activity, or any abnormal condition that increases the oxidation of the tissues, naturally results in an increased production of carbon dioxide, and an increase in the rate and depth of the respirations. On the other hand, an excess of oxygen in the blood may cause a condition known as *physiological apnœa*, *i.e.*, where the blood is so rich in oxygen and poor in carbon dioxide that a respiratory act is unnecessary.

Reflex stimulation of the respiratory centre. — Every one must have noticed that the respiratory movements are affected by stimulation of the sensory nerves. Strong emotion, sudden pain, or a dash of cold water on the skin produce changes in the rate of the respirations. It is assumed, therefore, that the respiratory centre is in connection with the sensory fibres of all the cranial and spinal nerves.

Cause of the first respiration. — The immediate cause of the first respiratory effort is closely connected with the cause of the activity of the respiratory centre during life. The stimulus is supposed to come from (1) the increased amount of carbon dioxide in the blood, due to the cutting of the umbilical cord; and (2) stimulation of the sensory nerves of the skin, due to cooler air, handling, etc. During intrauterine life the fœtus receives its supply of oxygen, and gives off carbon dioxide by means of the blood-vessels of the cord, which connect with the placenta. The lungs are in a collapsed condition and contain no air. The walls of the air-sacs are in close contact, and the walls of the smaller bronchial tubes, or bronchioles, touch one another. When the chest expands with the first breath, the inspired air has to overcome the adhesions existing between the walls of the bronchioles and air-sacs. The force of this first inspiratory effort, spent in opening out and unfolding, as it were, the inner recesses of the lungs, is considerable. In the succeeding expiration, most of the air introduced by the first inspiration remains in the lungs, succeeding breaths unfold the lungs more and more, until finally the air-sacs and bronchioles are all opened up and filled with air. The lungs thus once filled with air are never completely emptied again until after death.

Frequency of respiration. — The average rate of respiration for an adult is about eighteen per minute. Even in health this rate may be increased by muscular exercise, emotion, etc. Anything that affects the heart-beat will have a similar effect on the respirations and except in diseased conditions the ratio of the respirations and heart-beat (1 to 4) remains the same. Age has a marked influence. The average rate in the newly born infant has been found to be forty-four per minute, and at the age of five years, twenty-six per minute. It is reduced between the ages of fifteen and twenty to the normal standard.

Respiratory sounds. — The entry and exit of the air are accompanied by respiratory sounds or murmurs. These murmurs differ as the air passes through the trachea, the larger bronchial tubes, and the bronchioles. They are variously modified in lung disease, and are then often spoken of under the name of *râles.* In labored breathing the contraction of the respiratory muscles not usually brought into play, such as the muscles of the throat and nostrils, becomes very marked.

Effects of respiration upon the blood. — Once or twice each minute all the blood in the body passes through the capillaries of the lungs. This means that the time during which any portion of blood is in a position for respiratory exchange is only a second or two. Yet during this time, the following changes take place: (1) it loses carbon dioxide; (2) it gains oxygen, which combines with the reduced hæmoglobin of the red cells and turns it into oxyhæmoglobin, and as a result of this the crimson color shifts to scarlet; and (3) the temperature is slightly reduced.

It is helpful to compare the amounts of oxygen and carbon dioxide found in the venous blood brought to the lungs, and the amounts found in the arterial blood carried from the lungs.

	Oxygen	Carbon Dioxide	Nitrogen
Venous blood contains	8–12%	45–50%	1–2%
Arterial blood contains	20%	38%	1–2%

From these figures it is evident that the cells do not remove all the oxygen nor do the lungs remove all the carbon dioxide from the circulating blood. There is always a considerable amount of

oxygen in venous blood, also a considerable amount of carbon dioxide in arterial blood. Consequently, the main result of the respiratory exchange is to keep the gas content of the arterial blood nearly constant at the figures given. Under normal conditions it is not possible to increase appreciably the amount of oxygen absorbed by the blood flowing through the lungs.[1]

Capacity of the lungs. — As the lungs are not emptied at each expiration, neither are they filled. If filled to their utmost, they can hold a little more than one gallon (4500 c.c.) of air. This total is divided as follows: —

(1) Tidal.
(2) Complemental.
(3) Reserve.
(4) Residual.

Tidal air is the air introduced with every ordinary inspiration (30 cu. in. or about 500 c.c.).

Complemental air is the excess over the tidal air which may be introduced during a forced inspiration.

Reserve air is the amount of air in addition to the tidal air one can expel from the lungs in a forced expiration.

Residual air is the air remaining in the lungs after the most powerful expiration.

The vital capacity is the sum of the tidal, complemental, and reserve air added together. It equals about 225 cubic inches (3700 c.c.).

It is not correct to think of the residual air in the lungs as stationary, for the air is being constantly moved and renewed. This movement is maintained by: (1) the alternate expansion and collapse of the lungs in respiration, (2) the convection [2] currents due to the differences in temperature between the inspired air and the residual air, (3) the pulsation of the arteries, and (4) the difference in the proportion of carbon dioxide and oxygen in the inspired air and residual air. This fourth factor is also responsible for the interchange of gases between the air in the air-sacs and the

[1] Student nurses sometimes find it difficult to reconcile this fact with the practice of using pure oxygen in critical cases of pulmonary disease. The relief of the pneumonia patient who inhales pure oxygen is usually marked because the blood absorbs an increased amount of oxygen. The reason for this seeming contradiction is that normal blood cannot absorb an increased amount of oxygen, but in the case of the pneumonia patient the composition of the blood as regards oxygen is below normal, and the inhalation of pure oxygen brings it up to the standard, hence the marked relief.

[2] See Glossary, p. 494.

blood in the capillaries. The reason is that the blood contains more carbon dioxide and less oxygen than the air in the alveoli, and the tendency of gases is always to mix in uniform proportions.

The effects of respiration upon the air outside the body. — With every inspiration a well-grown man takes into his lungs about 30 cubic inches (500 c.c.) of air. The air he takes in differs from the air he gives out mainly in three particulars: —

1. Whatever the temperature of the external air, the expired air is nearly as hot as the blood; namely, of a temperature between 98° and 100° F. (36.7° and 37.8° C.).

2. However dry the external air may be, the expired air is quite, or nearly, saturated with moisture.

3. When breathed the air loses 4.94 per cent of oxygen and gains 4.38 per cent of carbon dioxide. Thus: —

	Oxygen	Carbon Dioxide	Nitrogen
Inspired air	20.96%	0.04%	79%
Expired air	16.02%	4.38%	79%
	4.94 loss	4.34 gain	0

Ventilation. — Since at every breath the external air gains carbon dioxide and loses oxygen, it was formerly taught that the general discomfort, headache, and languor that result from sitting in a badly ventilated room were due to the increase in carbon dioxide and the loss of oxygen. The results of many experiments seem to prove that people can become so accustomed to a high percentage of carbon dioxide and a low percentage of oxygen that they suffer little discomfort; though odors given off from the body and its clothing when present in any amount may affect the nervous system disagreeably. It is now thought that the injurious effects of remaining in a badly ventilated room are due to interference with the heat-regulating mechanism of the body. Under favorable conditions the surface of the human body is kept comfortably cool by the air currents which pass over it and by the evaporation of perspiration. The former are an aid to the latter. In a confined space there is a lack of movement in the air and it tends to become warm and humid. Moisture is not taken from the skin promptly and the temperature rises. This results in a

dilatation of the blood-vessels of the skin and an increased amount of blood is sent to the surface of the body, thereby increasing the unpleasant warmth. There is likely to be some reduction of the general blood-pressure leading to drowsiness or at least a feeling of inertia. In accordance with these views, the most effective precautions that can be taken to secure comfort in a room are to keep it cool and to have some circulation of the air. It has been shown that starting an electric fan in a close room may relieve an almost intolerable condition. It does not improve the air chemically but it favors the removal of heat from the bodies of the inmates and braces up their vasomotor systems. One writer suggests that the real difficulty with a stuffy room is that there is a lack of stimulation for the nervous system. One becomes relaxed and indolent because the nerve-endings in the skin are not being played upon as they would be by a constant change in environmental conditions. Because of these facts we are now taught that proper ventilation requires (1) there must be continuous movement of the air; (2) the temperature and degree of humidity must favor the evaporation of perspiration from the skin; (3) odors from skin, clothing, light, and other sources must be eliminated.

Dyspnœa. — The word dyspnœa means difficult breathing. It is caused by (1) an increase in the percentage of carbon dioxide in the blood, (2) a decrease in the oxygen, and (3) any condition that stimulates the sensory nerves and causes pain in the lungs.

Hyperpnœa. — The word hyperpnœa means excessive breathing and is applied to the initial stages of dyspnœa, when the respirations are simply increased.

Apnœa. — The word apnœa means a lack of breathing.

Cheyne-Stokes respirations. — This is a type of respirations which was first described by the two physicians whose names it bears. It appears in two forms: (1) the respirations increase in force and frequency up to a certain point, and then gradually decrease until they cease altogether, and there is a short period of apnœa, then the respirations recommence and the cycle is repeated. (2) The respirations increase in force and frequency up to a certain point, then cease, and the period of apnœa intervenes, without the gradual cessation of the respirations. This condition is associated with disease of the kidney, brain, or heart. The cause is

not settled, but it is of bad prognosis and generally indicates a fatal termination.

Œdematous respiration. — When the air cells become infiltrated with fluid from the blood, the breathing becomes œdematous and is recognized by the moist, rattling sounds, called râles, that accompany each inspiration. It is a serious condition be-

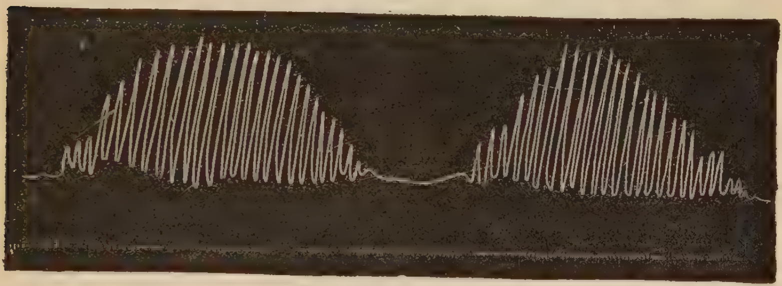


FIG. 160. — STETHOGRAPH TRACING OF CHEYNE-STOKES RESPIRATIONS IN A MAN. The time is marked in seconds. (Halliburton.)

cause it interferes with aëration of the blood and often results in asphyxia.

Asphyxia. — This condition is usually the sequel to severe dyspnœa and œdematous respiration. It is produced by any condition that causes prolonged interference with the aëration of the blood. After death from asphyxia it will be found that the right side of the heart, the pulmonary arteries, and the systemic veins are overloaded, and the left side of the heart, the pulmonary veins, and the systemic arteries are empty.

MODIFIED RESPIRATORY MOVEMENTS

Various emotions may be expressed by means of the respiratory apparatus.

Sighing is a deep and long-drawn inspiration, followed by a sudden expiration.

Yawning is an inspiration, deeper and longer continued than a sigh, drawn through the widely open mouth, and accompanied by a peculiar depression of the lower jaw.

Hiccough is caused by a sudden inspiratory contraction of the diaphragm; the glottis suddenly closes and cuts off the column of air just entering, which, striking upon the closed glottis, gives rise to the characteristic sound.

Sobbing is a series of convulsive inspirations during which the glottis is closed, so that little or no air enters the chest.

Coughing consists, in the first place, of a deep and long-drawn inspiration by which the lungs are well filled with air. This is followed by a complete closure of the glottis, and then comes a forcible and sudden expiration, in the midst of which the glottis suddenly opens, and thus a blast of air is driven through the upper respiratory passages.

Sneezing consists of a deep inspiration, followed by a sudden and forced expiration, which directs the air through the nasal passages.

Laughing consists essentially in an inspiration, followed by a whole series of short, spasmodic expirations, the glottis being freely open during the whole time, and the vocal cords being thrown into characteristic vibrations.

Crying consists of the same respiratory movements as laughing; the rhythm and the accompanying facial expressions are, however, different, though laughing and crying often become indistinguishable.

Speaking consists of a voluntary expiration and the vibration of the vocal cords as the air passes over them.

SUMMARY

Respiration is dependent upon the proper functioning of organs that comprise the respiratory system. Air passes through the nose or mouth to these organs.

- **Nose**
  - **Function**
    - Special organ of the sense of smell.
    - Passageway for entrance of air to the respiratory organs.
  - **External nose**
    - Framework of bone (nasal) and cartilage.
    - Covered with skin, lined with mucous membrane known as pituitary, or Schneiderian.
    - Nostrils are oval-shaped openings on under surface, separated by a partition.
  - **Internal cavities, or nasal fossæ**
    - Extend from nostrils to the pharynx.
    - Two wedge-shaped cavities.
    - Formed by
      - 2 palate.
      - 2 maxillæ.
      - 1 ethmoid.
      - 1 sphenoid.
      - 2 nasal.
      - 2 turbinated, and processes of the ethmoid
        - Superior meatus.
        - Middle meatus.
        - Inferior meatus.
      - 1 vomer.
      - 11 bones.
  - **Advantages of nasal breathing**
    - Air
      - Warmed.
      - Moistened.
      - Filtered.
  - **Communicating sinuses**
    1. Frontal.
    2. Ethmoidal.
    3. Maxillary or antrums of Highmore.
    4. Sphenoidal.
- **Respiratory System**
  1. Larynx.
  2. Trachea.
  3. Bronchi.
  4. Lungs.
- **Larynx**
  - Special organ of voice.
  - Triangular box made up of nine pieces of cartilage.
  - Situated between the tongue and trachea.
  - Contains vocal cords.
  - Slit or opening between cords called *glottis*, which is protected by leaf-shaped lid called epiglottis.
  - Connected with external air by
    - Mouth.
    - Nose.

- **Voice**
  - Produced by vibrations of vocal cords.
  - Resonating cavities
    - Pharynx.
    - Mouth.
    - Nasal cavities.
  - Lower pitch of male voice is due to greater length of vocal cords.
- **Trachea**
  - Fibrous and muscular tube, $4\frac{1}{2}$ in. long.
  - Strengthened by C-shaped hoops of cartilage
    - Complete in front.
    - Incomplete behind.
  - In front of œsophagus.
  - Extends from larynx to fifth thoracic vertebra, where it divides into two bronchi.
- **Bronchi**
  - Right and left — structure similar to trachea.
  - Right
    - 1 in. long.
    - Almost horizontal.
  - Left
    - 2 in. long.
    - Almost vertical.
  - Divide into innumerable bronchial tubes or bronchioles.
- **Lungs**
  - **Location** — Occupy all of the cavity of the thorax that is not taken up by the heart, blood-vessels, lymphatics, œsophagus, and lymph nodes.
  - **Cone-shaped organs**
    - Outer surface convex to fit in concave cavity.
    - Base concave to fit over convex diaphragm.
    - Apex rises half an inch above the clavicle.
    - Hilum or depression on inner surface gives passage to bronchi, blood-vessels, lymphatics, and nerves.
  - **Right**
    - Larger, heavier, broader, shorter — three lobes.
  - **Left**
    - Smaller, narrower, longer, front border deeply indented — two lobes.
  - **Anatomy**
    - Hollow, spongy organs. Consist of bronchial tubes — infundibula — alveoli, also blood-vessels, lymphatics, and nerves held together by connective tissues.
  - **Blood-vessels**
    - **Pulmonary artery**
      - Blood for aëration.
      - Accompanies bronchial tubes.
      - Plexus of capillaries around alveoli.
      - Returned by pulmonary veins.
    - **Bronchial arteries** — supply lung substance.
  - **Nerves**
    1. Branches from the sympathetic system.
    2. Branches from the vagi.

- **Pleura**
  - Closed sac. Envelops lungs, but they are not in it.
  - Two layers
    - Visceral — next to lung
    - Parietal — outside of visceral
    - Moistened by serum.
  - **Function** — To lessen friction.
- **Mediastinum** — Space between pleural sacs. Extends from sternum to spinal column.
- **Respiration**
  - **Function**
    - Increase the amount of oxygen.
    - Decrease the amount of carbon dioxide.
    - Help to maintain temperature.
    - Help to eliminate waste.
  - **Processes**
    - **Breathing**
      - **Inspiration** — Process of taking air into lungs.
      - **Expiration** — Process of expelling air from lungs.
    - **External Respiration**
      - External oxygen supply
      - External carbon dioxide elimination
      - Takes place in the lungs.
    - **Internal Respiration**
      - Internal oxygen supply
      - Internal carbon dioxide elimination
      - Takes place in the cells.
- **Mechanism of Inspiration and Expiration**
  - **Inspiration**
    - Chest cavity enlarged
      - Elevation of ribs.
      - Descent of diaphragm.
    - Lungs expand.
    - Air rushes in through trachea and bronchi.
  - **Expiration**
    - Chest cavity made smaller
      - Inspiratory muscles relax.
      - Recoil of elastic thorax.
      - Recoil of elastic lungs.
    - Air forced out through trachea.
- **Cause of Respiration**
  1. **Respiratory centre** — Action is automatic. Assumed to be in connection with all the cranial and spinal nerves.
  - Rate and rhythm controlled by
    - Vagi nerves
      - Inspiratory — tend to increase rate.
      - Expiratory — check the action of the inspiratory set.
    - Carbon dioxide content of blood.

Cause of First Respiration
1. Increased amount of carbon dioxide due to cutting of the umbilical cord.
2. Reflex, due to stimulation of the sensory nerves of the skin.

Respiratory Rate
- 18 times per minute.
- Ratio to pulse 1 to 4.
- Influenced by
  - Muscular exercise.
  - Emotion.
  - Heart-beat.
  - Age.

Effect of Respiration upon the Blood
1. Loses about 10% of carbon dioxide.
2. Gains about 10% of oxygen
   - Oxyhæmoglobin.
   - Scarlet color.
3. Temperature is slightly reduced.

Capacity of Lungs
- A little more than 1 gallon of air (4500 c.c.)
  - Tidal
  - Complemental
  - Reserve
  - Residual
- Tidal, Complemental, Reserve: Vital capacity 3700 c.c.

Movement of Residual Air Maintained by
1. Alternate expansion and collapse of lungs.
2. Convection currents.
3. Pulsation of the arteries.
4. Diffusion of gases.

Effect of Respiration upon the Air outside the Body
1. Temperature increased. Expired air is as hot as blood.
2. Moisture increased. Expired air is saturated with moisture.
3. Oxygen decreased by 4.94%.
4. Carbon dioxide increased by 4.34%.

Proper Ventilation
1. Continuous movement of the air.
2. The temperature and degree of humidity must favor the evaporation of perspiration from the skin.
3. Disagreeable odors must be eliminated.

Abnormal Types of Respiration
- Dyspnœa — difficult breathing.
- Hyperpnœa — excessive breathing.
- Apnœa — lack of breathing.
- Cheyne-Stokes
  1. Respirations increase in force and frequency, then gradually decrease and stop. Cycle repeated.
  2. Respirations increase in force and frequency up to a certain point, then stop. Cycle repeated.
- Œdematous — air cells filled with fluid, hence moist, rattling sounds.
- Asphyxia — oxygen starvation.

CHAPTER XIV

THE DIGESTIVE SYSTEM: ALIMENTARY CANAL AND ACCESSORY ORGANS

In complex multicellular bodies, the cells where food is needed are so far removed from the points of entrance of food material, that it is necessary that these foods should be changed physically and chemically into such standard substances as can diffuse into the blood system and be carried by the blood to all the cells of the body and diffuse into them. Chemical and physical changes necessary to reduce our varied foods to such standard substances as the tissues can use are effected in certain organs that are grouped together and called the digestive system.

THE DIGESTIVE SYSTEM

The digestive system consists of the alimentary canal and the accessory organs: (1) the salivary glands, (2) the tongue, (3) the teeth, (4) the pancreas, and (5) the liver.

ALIMENTARY CANAL

The alimentary canal is a continuous tube which extends from the mouth to the anus. It measures about 30 feet (9 m.) in length, the greater part being coiled up in the cavity of the abdomen. The portion above the diaphragm is composed of three coats; and the portion below the diaphragm is composed of four coats. Beginning at the inner lining these coats are: —

(1) The **mucous**.	Both described in
(2) The **areolar** or sub-mucous.	Chapter VIII

(3) The **muscular** coat consists almost entirely of non-striated muscular tissue, usually arranged in two layers. The internal cells are circular in direction, and the external cells run longitudinally. By the alternate contraction and relaxation of cells arranged in this fashion (the contractions starting from above), the contents of the tube are propelled from above downward.

(4) **The serous coat** is derived from the peritoneum.

The peritoneum. — This is the largest serous membrane in the body and in the male consists of a closed sac,[1] the parietal layer of which lines the walls of the abdominal cavity; the inner or visceral layer is reflected over the abdominal organs, and the upper surface of some of the pelvic organs. The arrangement of the peritoneum is very complex, for several elongated sacs and double folds extend from it, to pass in between and either wholly or partially surround the viscera of the abdomen and pelvis. One important fold is the *omentum*, which hangs like a curtain in front of the stomach and the intestines; another is the *mesentery*, which is a continuation of the serous coat and attaches the small and much of the large intestine to the spine.

When the abdominal cavity is opened, the intestines appear to lie within the cavity like a loose coil of rope. If, however, an attempt is made to lift a coil from its place a clear, glistening sheet of tissue is found attached to it. This is the mesentery. The posterior portion is gathered into folds which are attached to the spine along a short line of insertion which results in a structure that has the appearance of a ruffle or flounce.

Functions of the peritoneum. — Like all serous membranes the peritoneum serves to prevent friction between contiguous organs by secreting serum which acts as a lubricant. To a limited extent it serves to hold the abdominal and pelvic organs in position, also unites and separates these organs. In addition to these functions, the omentum usually contains fat, and serves to keep the organs it covers warm.

Divisions of the alimentary canal. — For convenience of description, the alimentary canal may be divided into: —

Mouth, containing tonsils, tongue, salivary glands, and teeth.
Pharynx.
Œsophagus.
Stomach.

Small or thin intestine	Duodenum.	
	Jejunum.	
	Ileum.	
Large or thick intestine	Cæcum.	
	Colon. →	Ascending.
		Transverse.
		Descending.
	Rectum.	

[1] In the female the peritoneum is not a closed sac, because the Fallopian tubes open into it at their extremities.

MOUTH, OR BUCCAL CAVITY

The mouth cavity is a nearly oval-shaped cavity with a fixed roof anteriorly, a flexible roof posteriorly, and a movable floor. It is bounded in front by the lips, on the sides by the cheeks, below by the tongue, and above by the palate.

The palate. — The palate consists of a hard portion in front formed by bone[1] covered by mucous membrane, and of a soft portion behind containing no bone. The hard palate forms the partition between the mouth and nose; the soft palate arches backward and hangs like a curtain between the mouth and the pharynx. Hanging from the middle of its lower border is a pointed portion of the soft palate called the *uvula* (little grape).

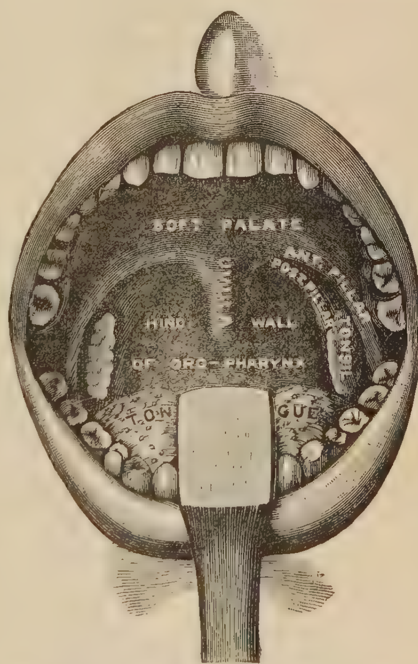


FIG. 161. — THE SOFT PALATE AND TONSILLAR REGIONS. (Gerrish.)

Fauces. — The fauces is the name given to the aperture leading from the mouth into the pharynx, or throat cavity.

Pillars of the fauces. — From the base of the uvula on either side there passes a curved fold of muscular tissue covered by mucous membrane, which shortly after leaving the uvula is, as it were, split into two pillars, the one going outward, downward, and forward, passing to the side of the tongue, the other outward, downward, and backward to the side of the pharynx. These pillars are known respectively as the *anterior* and the *posterior* pillars of the fauces.

Tonsils. — In the lower part of the triangular space between the anterior and posterior pillars, on either side, lie the small masses

[1] Processes of the maxillæ and palate bones.

of lymphoid tissue called tonsils. They consist of a collection of lymph nodules held together by a distinct capsule and covered on their exposed surface by mucous membrane.

Function. — The function of the tonsils is imperfectly understood. They may be a source of lymphocytes and leucocytes, or they may act as filters and prevent the entrance of microörganisms. Inflammation of the tonsils is called tonsillitis.

The palate, uvula, pillars of the fauces, and tonsils are plainly seen if the mouth is widely opened and the tongue depressed.

The tongue. — The tongue[1] is the special organ of the sense of taste and assists in speech. It has also to be considered with reference to digestion, (1) because stimulation of the nerves of the sense of taste starts the secretion of digestive fluids, (2) it assists in swallowing, and (3) the follicles at the back of the tongue secrete mucus, which lubricates the food and makes swallowing easier.

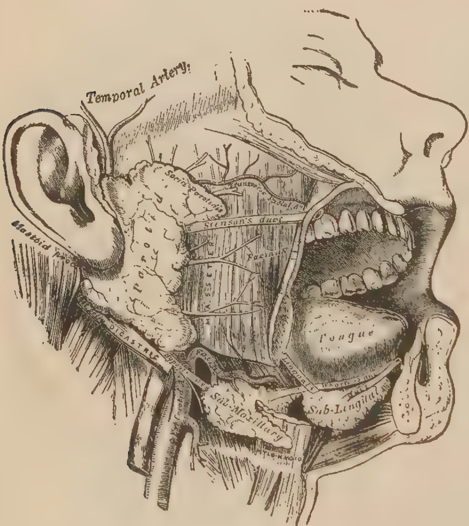


Fig. 162. — The Salivary Glands.

The salivary glands. — The mucous membrane lining the mouth contains many minute glands consisting of just one cell. These are called goblet cells and pour their secretion upon its surface, but the chief secretion of the mouth is supplied by the salivary glands, which are three pairs of compound saccular glands called the parotid, submaxillary, and sublingual, respectively. Each *parotid* gland is placed just under and in front of the ear; its duct (Stenson's) passes forward along the cheek, until it opens into the interior of the mouth opposite the second molar tooth of the upper jaw. The *submaxillary* and *sublingual* glands are situated below the jaw and under the tongue, the submaxillary being

[1] A detailed description of the tongue will be found in Chapter XX.

placed farther back than the sublingual. One duct from each submaxillary and a number of small ducts from each sublingual open in the floor of the mouth beneath the tongue. The secretion of these salivary glands, mixed with that of the small glands of the mouth, is called saliva.

Secretory nerves. — The salivary glands receive a double nerve supply, — in part from the cranial nerves and in part from the sympathetic system. These nerves are called secretory because they control the activity of the cells which form the secretion. Not only are secretory nerves distributed to these glands, but vasomotor fibres are contained in the same nerves. The cranial nerves contain vaso-dilator fibres. Stimulation of these causes a dilatation of the small arteries and an increased blood-flow; while the sympathetic carries vaso-constrictor fibres that constrict the arteries and diminish the blood-flow.

The teeth. — The semicircular borders of the upper and lower jaw-bones (the alveolar processes) contain sockets for the reception of the teeth. A dense, insensitive, fibrous membrane covered by smooth mucous membrane — the gums — covers these processes and extends a little way into each socket. These sockets are lined by periosteum, which connects with the gums and serves (1) to attach the teeth to their sockets, and (2) as a source of nourishment.

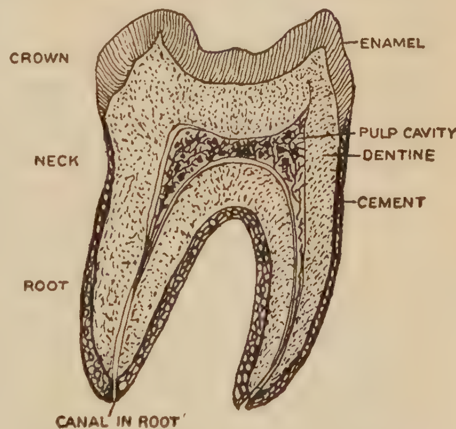


FIG. 163. — SECTION OF HUMAN MOLAR TOOTH. (Adapted from Dalton.)

Each tooth consists of three portions: (1) the *root*, consisting of one or more fangs contained in the socket; (2) the *crown*, which projects beyond the level of the gums; and (3) the *neck* or constricted portion between the root and the crown, which is enveloped by the gum.

Each tooth is composed principally of *dentine*, which gives it shape and encloses a cavity, the pulp cavity. The dentine of the crown is capped with a dense layer of *enamel*. The dentine of the

root is covered by *cement*. These three substances, enamel, dentine, and cement, are all harder than bone, enamel being the hardest substance found in the body. They are developed from epithelial tissue. The pulp cavity is just under the crown and is continuous with a canal that traverses the centre of each root, and opens by a small aperture at its extremity. It is filled with dental pulp, which consists of loose connective tissue holding a number of blood-vessels and nerves which enter by means of the canal from the root.

There are two sets of teeth developed during life: the first, temporary or deciduous; and the second, permanent.

Temporary teeth. — In the first set are twenty teeth, ten in each jaw: four incisors, two canines, and four molars. The cutting of the temporary teeth usually begins at six months and ends at about the age of two years.[1] In nearly all cases the teeth of the lower jaw appear before the corresponding ones of the upper jaw.

TEMPORARY TEETH

	MOLARS	CANINE	INCISORS	CANINE	MOLARS
Upper . . .	2	1	4	1	2
Lower . . .	2	1	4	1	2

Permanent teeth. — During childhood the temporary teeth are replaced by the permanent. In the second set are thirty-two permanent teeth, sixteen in each jaw. The first molar usually appears between five and seven years of age.[2]

PERMANENT TEETH

	MOLAR	BICUSPID	CANINE	INCISOR	CANINE	BICUSPID	MOLAR
Upper	3	2	1	4	1	2	3
Lower	3	2	1	4	1	2	3

[1] The temporary teeth are usually cut in the following order: —

Lower central incisors	6 to 9 months
Upper incisors	8 to 10 months
Lower lateral incisors and first molars	15 to 21 months
Canines	16 to 20 months
Second molars	20 to 24 months

[2] The permanent teeth appear at the following periods: —

First molars	6½ years
Two middle incisors	7th year
Two lateral incisors	8th year
First bicuspid	9th year
Second bicuspid	10th year
Canine	11th to 12th year
Second molars	12th to 13th year
Third molars	17th to 21st year

According to their shape and use the teeth are divided into incisors, canines, bicuspids, and molars.

Incisors are eight in number and form the four front teeth of each jaw. They have wide, sharp edges, and are specially adapted for cutting food.

Canines are four in number, two in each jaw. The upper canines are commonly called eye-teeth; the lower, stomach teeth. They have sharp, pointed edges and are longer than the incisors. In the human being they serve the same purpose as the incisors.

Bicuspids are eight in number in the permanent set. There are none in the temporary set. There are four in each jaw, two being placed just behind each of the canine teeth.

They are broad, with two points or cusps on each crown; these teeth have only one root; the root, however, being more or less completely divided into two. Their function is to cut and grind food.

Molars are twelve in number in the permanent set, and only eight in the temporary set.

The molars, or true grinders, have broad crowns with small, pointed projections, which make them well fitted for crushing and bruising the food: they each have two or three roots. The twelve molars do not replace the temporary teeth, but are gradually added with the growth of the jaws; the last or hindmost molars may not appear until twenty-one years of age; hence called *late teeth* or *wisdom teeth*."

Function. — The teeth assist in the process of mastication by cutting and grinding the food. It might be thought that the vigorous employment of the teeth for this purpose would only hasten their wear and tear. This may be true at a time when their life is nearly extinct, but at an earlier period mastication is good for the teeth because they are made to sink and rise in their sockets with a massaging effect upon the gums which tends to promote circulation in the pulp.

THE PHARYNX

The pharynx, or throat cavity, is that part of the alimentary canal which is behind the nose, mouth, and larynx. It is a musculo-membranous tube shaped somewhat like a cone, with its broad end turned upward and its constricted end downward

to end in the œsophagus. It is about five inches (12.5 cm.) in length. Above, it is attached to the base of the skull, and behind, to the cervical vertebræ; in front and on each side are apertures which communicate with the nose, ears, mouth, and larynx.

Of these apertures there are **seven**:—

Two in front above, leading into the back of the nose, the posterior nares.

Two, one on either side above, leading into the Eustachian tubes, which communicate with the ears.

One midway in front, the fauces.

Two below, one opening into the larynx and the other into the œsophagus.

The mucous membrane lining the pharynx is well supplied with glands, and at the back of the cavity there is a considerable mass of lymphoid tissue. During infancy and childhood this may increase to such an extent that it interferes with nasal breathing. The child is then said to have *adenoids* and is obliged to breathe through the mouth; hence the term "mouth breathers."

Function. — The muscular tissue in the walls of the pharynx is of the striped variety, and when the act of swallowing is about to be performed, the muscles draw the pharynx upward and dilate it to receive the food; they then relax, the pharynx sinks, and the other muscles contracting upon the food, it is pressed downward and onward into the œsophagus.

THE ŒSOPHAGUS, OR GULLET

The œsophagus is a comparatively straight tube, about nine inches (22. cm.) long, which commences at the lower end of the pharynx, behind the trachea. It descends in front of the spine, passes through the diaphragm, and terminates in the upper or cardiac end of the stomach.

Structure. — The walls of the œsophagus are composed of three coats: (1) an external or muscular, (2) a middle or areolar, and (3) an internal or mucous, coat. The muscular coat is arranged in an external longitudinal and an internal circular layer. Contraction of the outer layer produces dilatation of the tube; contraction of the inner, constriction. Consequently this arrange-

ment is of importance in the movements which carry the food from the pharynx to the stomach. These movements are called peristaltic, and consist of contractions of the longitudinal layer, followed by contractions of the circular layer. The areolar coat serves to connect the muscular and mucous coats. The mucous mem-

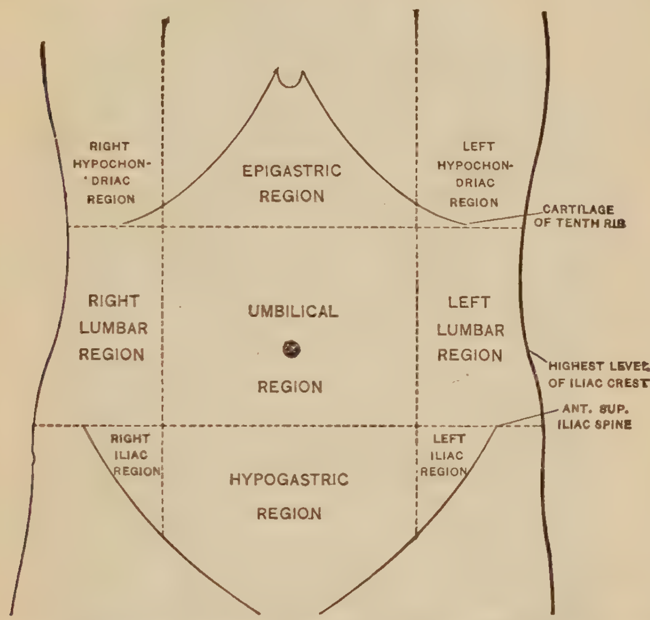


FIG. 164. — REGIONS OF THE ABDOMEN. (Gerrish.) The following structures are found within the cavity: — 1. The greater part of the alimentary canal, viz., stomach, small intestine, and large intestine. 2. Digestive glands: the liver and pancreas. 3. Ductless glands: the spleen and the two supra-renal glands. 4. Urinary apparatus: the kidneys, ureters, bladder and part of urethra. 5. The internal generative organs, according to the sex. 6. Blood-vessels and lymph vessels, and lymph nodes. 7. The abdominal portion of the central and sympathetic nervous systems. 8. The peritoneum — the serous membrane which lines the cavity, and is reflected over most of its contained viscera.

brane is disposed in longitudinal folds which disappear upon distention of the tube.

Function. — The œsophagus serves (1) to connect the pharynx with the stomach, and (2) to receive the food from the pharynx and by a series of peristaltic contractions pass it on to the stomach.

Regions of the abdomen. — That portion of the alimentary canal which is below the thorax is contained in the abdomen. For convenience of description, the abdomen may be artificially

divided into nine regions by drawing the following arbitrary lines: —

1. Draw a circular line around the body at the level of the tenth costal cartilages.

2. Draw another circular line at the level of the anterior superior spines of the ilia.

3. Draw a vertical line on each side from the centre of Poupart's ligament upward.

These lines are to be considered as edges of planes which divide the abdomen into the nine regions illustrated in Fig. 164.

THE STOMACH

After the œsophagus perforates the diaphragm it ends in the stomach (gaster), which is the most dilated portion of the alimentary canal and serves as a temporary receptacle for food. It lies obliquely or horizontally in the epigastric and left hypochondriac

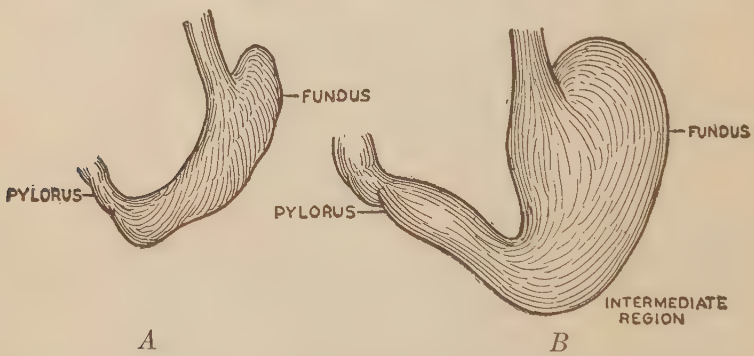


FIG. 165. — FORM AND OUTLINE OF THE STOMACH AT DIFFERENT STAGES OF DIGESTION. *A*, when empty and contracted. *B*, at an early stage of gastric digestion.

regions of the abdomen, directly under the diaphragm. The shape and position of the stomach are modified by changes within itself, and in the surrounding organs. These modifications are determined by (1) the amount of the stomach contents, (2) the stage of digestion which has been reached, (3) the degree of development and power of the muscular walls, and (4) the condition of the adjacent intestines. When empty or contracted the shape of the stomach is comparable to a sickle or sausage. At an early stage of gastric digestion, the stomach usually consists of two segments,

a large globular portion on the left, and a narrow tubular portion on the right. When distended with food it has the shape shown in Fig. 166.

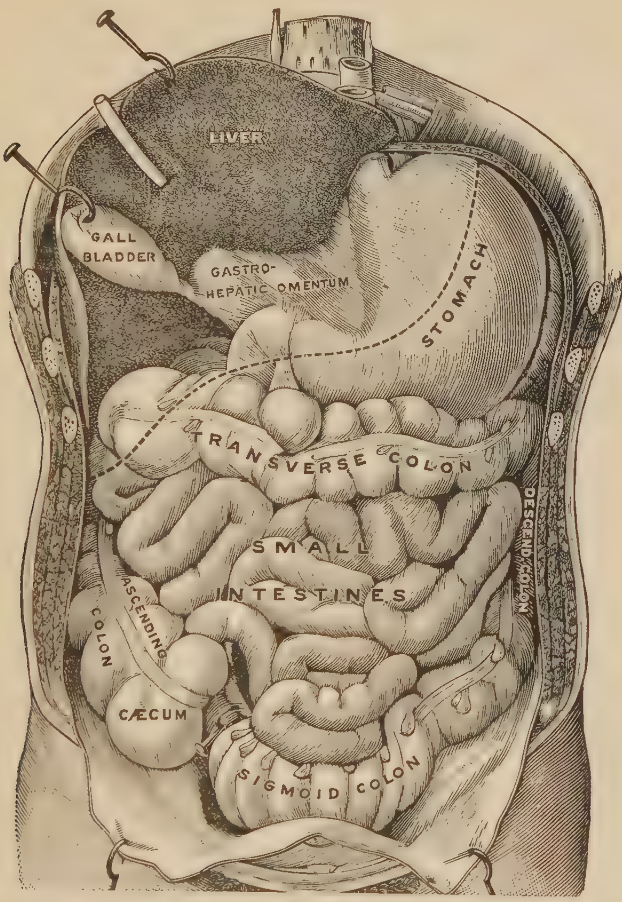


FIG. 166. — THE STOMACH AND INTESTINES, FRONT VIEW, THE GREAT OMENTUM HAVING BEEN REMOVED, AND THE LIVER TURNED UP AND TO THE RIGHT. The dotted line shows the normal position of the anterior border of the liver. (Gerrish.)

The stomach presents two openings and two borders or curvatures.

Openings. — The opening by which the œsophagus communicates with the stomach is known as the cardiac or œsophageal orifice, and the orifice which communicates with the duodenum is known as the pyloric. Both the cardiac and pyloric apertures are guarded by strong bands of muscle which are in a state of contrac-

tion during digestion. By this arrangement, the food is kept in the stomach until it is ready for intestinal digestion, when the circular fibres guarding the pyloric aperture relax. The acidity of the stomach contents seems to produce this relaxation.

Curvatures. — In all positions the stomach is more or less curved upon itself. A line drawn from the cardiac orifice along the concave border to the pyloric orifice is said to follow the lesser curvature. A much longer line connecting the same points, but following the convex border, defines the greater curvature.

Component parts. — The fundus is the blind rounded end of the stomach to the left of the heart. The opposite or smaller end is called the pyloric extremity and lies under the liver. The central portion between the fundus and pyloric extremity is called the intermediate region.

Structure. — The wall of the stomach consists of four coats: (1) serous, (2) muscular, (3) submucous or areolar, and (4) mucous.

(1) The **serous** coat is formed by a fold of the peritoneum. This fold is thrown over the stomach and covers it before and behind. The anterior and posterior folds unite at the lower border and form an apron-like appendage, the *omentum*, which is suspended in front of the intestines.

(2) The **muscular** coat of the stomach is beneath the serous coat and closely connected with it. It consists of three layers of unstriped muscular tissue: an outer, longitudinal layer; a middle or circular layer; and an inner, less well-developed, oblique layer.

(3) The **submucous** coat consists of loose areolar tissue connecting the muscular and mucous coats. It carries nerves and vessels.

(4) The **mucous** coat is very soft and thick, the thickness being mainly due to the fact that it is densely packed with small glands. It is covered with columnar epithelium, and in its undistended condition is thrown into folds or rugæ. The surface is honeycombed by tiny, shallow pits, into which the ducts or mouths of the glands open.

Gastric glands. — The gastric glands are of three varieties, (1) cardiac; (2) true gastric or peptic; and (3) pyloric.

(1) Cardiac glands are simple tubular glands found about the cardiac or œsophageal orifice. They secrete mucus.

(2) True gastric or peptic glands are simple tubular glands distributed throughout the fundus and intermediate region of the stomach and may even be found at the pylorus. These glands are lined by epithelial cells of which there are two varieties. (*a*) One variety of cell is found lining the lumen of the tube. These are called chief cells and secrete pepsinogen. (*b*) A second variety called parietal cells are found behind the chief cells, where they do not come in contact with the lumen. These cells secrete acid, and pepsinogen in the presence of acid is converted into pepsin.

(3) Pyloric glands are branched tubular glands found most plentifully about the pylorus. They secrete pepsinogen and mucus.

FIG. 167. — PORTION OF TRUE GASTRIC OR PEPTIC GLAND.

The combined secretion of these glands forms the gastric fluid.

Nerves and blood-vessels. — The stomach is supplied with nerves from the sympathetic system, and also with branches from the vagus nerve, which comes from the central nervous system. The blood-vessels are derived from the three divisions of the cœliac axis, *i.e.*, gastric, and branches of the hepatic and splenic.

Functions. — The functions of the stomach are (1) to connect the œsophagus with the intestine, (2) to receive the food and hold it while it undergoes certain mechanical processes which reduce it to the consistency of thick soup, and also while it undergoes certain chemical changes brought about by secretion of the gastric glands, (3) to secrete mucus and gastric fluid.

THE SMALL, OR THIN, INTESTINE

The small intestine extends from the stomach (pyloric valve) above to the large intestine (valve of the colon) below. It is a convoluted tube about twenty feet (6 m.) in length, and fills

the greater part of the front abdominal cavity. Its diameter at the beginning is about two inches (5 cm.), but it gradually diminishes in size and is hardly an inch (2.5 cm.) in diameter at its lower end. The small intestine is divided by anatomists into three portions: — the duodenum, jejunum, and ileum.

The duodenum. — The duodenum is twelve fingers' breadth in length (ten inches or 25 cm.), and is the widest part of the small intestine. It extends from the pyloric end of the stomach to the jejunum.

Beginning at the pylorus, the duodenum at first passes upward and backward to the under surface of the liver; it then makes a complete bend and passes downward in front of the kidney; it again turns in a right angle direction to the left and passes horizontally across the front of the vertebral column. This third portion of the duodenum lies retroperitoneally, so that only its anterior aspect is covered by peritoneum. The small intestine now passes forward so as to leave the posterior abdominal wall, and becomes completely invested by peritoneum and has a true mesentery. The point at which it becomes completely invested by peritoneum marks the termination of the duodenum and the beginning of the jejunum.

The jejunum. — The jejunum or empty intestine, so called because it is always found empty after death, constitutes about two-fifths of the remainder, or seven and a half feet (2.2 m.), of the small intestine, and extends from the duodenum to the ileum.

The ileum. — The ileum, or twisted intestine, so called from its numerous coils, constitutes the remainder of the small intestine, and extends from the jejunum to the large intestine, which it joins at a right angle.

There is no definite landmark to determine the point at which the jejunum ceases and the ileum begins, although the mucous membrane of the one differs somewhat from the mucous membrane of the other; the change is a gradual transition, and one structure shades off into the other. The lengths in feet as given are arbitrary, but those usually accepted.

Coats of the small intestine. — The small intestine has four coats, which correspond in character and arrangement with those of the stomach.

(1) The **serous** coat furnished by the peritoneum forms an al-

most complete covering for the whole tube except for part of the duodenum.

(2) The **muscular** coat of the small intestine has only two layers: an outer, thinner and longitudinal; and an inner, thicker and circular. This arrangement is necessary for the peristaltic action of the intestine.

FIG. 168. — PORTION OF SMALL INTESTINE LAID OPEN TO SHOW VALVULÆ CONNIVENTES. Not highly enough magnified to show villi on valvulæ conniventes. (Collins.)

(3) The **submucous**, or areolar coat, carries blood-vessels, lymphatics, and nerves.

(4) The **mucous** coat is thick and very vascular.

Valvulæ conniventes. — About one or two inches beyond the pylorus the mucous and submucous coats of the small intestine are arranged in circular folds called valvulæ conniventes. Some of these folds extend all the way around the circumference of the intestine; others extend only one-half or one-third of the way. Unlike the rugæ of the stomach, the valvulæ conniventes do not disappear when the intestine is distended. About the middle of the jejunum they begin to decrease in size, and in the lower part of the ileum they almost entirely disappear. The purpose of the valvulæ conniventes is: (1) to prevent the food from passing through the intestines too quickly, and (2) to present a greater surface for the absorption of digested food.

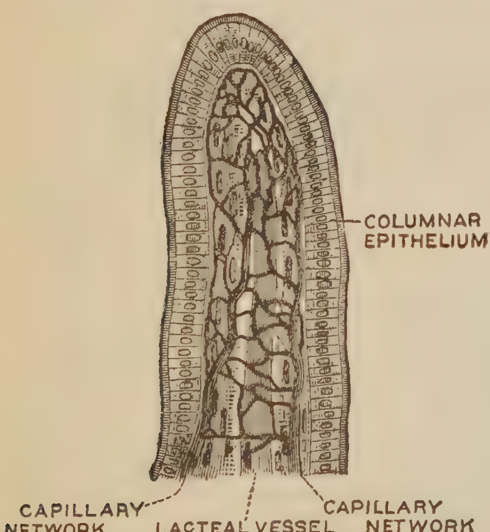


FIG. 169. — AN INTESTINAL VILLUS. (Highly magnified.)

Villi. — Throughout the whole length of the small intestine the

mucous membrane presents a velvety appearance due to minute finger-like projections called villi. Each villus consists of a central lymph channel called a lacteal, surrounded by a network of blood capillaries, held together by lymphoid tissue. This in turn is surrounded by a layer of columnar cells. After the food has been digested it passes into the capillaries and lacteals of the villi, so that this arrangement increases the surface for absorption.

Glands and nodes of the small intestine. — Besides these projections formed for absorption the mucous membrane is thickly studded with secretory glands and nodes. These are known as —

1. Simple follicles or crypts of Lieberkuhn.
2. Duodenal or Brunner's glands.
3. Lymph nodules { (a) Solitary lymph nodules. (b) Aggregated lymph nodules.

(1) *Simple follicles.* — These glands are found over every part of the surface of the small intestine. They are simply tubular

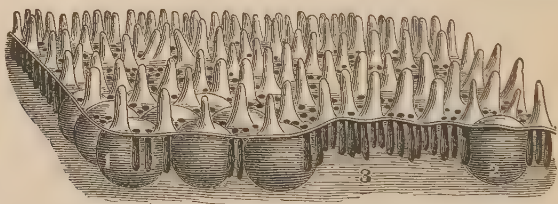


FIG. 170. — PORTION OF THE MUCOUS MEMBRANE, FROM THE ILEUM. Moderately magnified, exhibiting the villi on its free surface, and between them the orifices of the tubular glands. 1, portion of an aggregated lymph nodule; 2, a solitary lymph nodule; 3, fibrous tissue. (Dalton.)

depressions in the mucous membrane, lined with columnar epithelium.

(2) *Duodenal glands.* — These glands are better known as Brunner's glands. They are compound glands found in the submucous tissue of the duodenum. The simple follicles and the duodenal glands secrete the intestinal digestive fluid which is named the succus entericus.

(3) *Lymph nodules.* — These are of two varieties, (a) solitary lymph nodules, (b) aggregated lymph nodules of Peyer.

(a) *Solitary lymph nodules.* — Closely connected with the lymphatic vessels in the walls of the intestines are small, rounded bodies of the size of a small pin's head, called solitary lymph nodules. These bodies consist of a rounded mass of fine lym-

phoid tissue, the meshes of which are crowded with leucocytes. Into this mass of tissue one or more small arteries enter and form

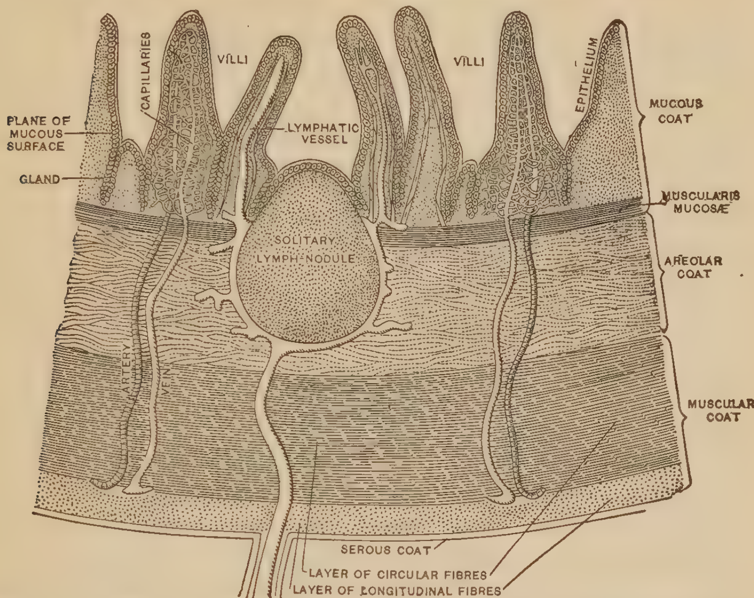


FIG. 171. — MUCOSA OF SMALL INTESTINE IN IDEAL VERTICAL CROSS-SECTION. (Gerrish.)

a capillary network, from which the blood is carried away by one or more small veins. Surrounding the mass are lymph channels which are continuous with the lymphatic vessels in the tissue below.

Aggregated lymph nodules. — They are simply collections of lymph nodules, commonly called Peyer's patches. A well-formed Peyer's patch consists of fifty or more of these solitary lymph nodules, arranged in a single layer close under the epithelium of the intestinal mucous membrane, and stretching well down into the tissue beneath. These patches are circular or oval in

FIG. 172. — AGGREGATED LYMPH NODULE (Peyer's Patch). (Gerrish.)

shape, from ten to sixty in number and vary in length from one-half inch to four inches (1.25 to 10 cm.). They are largest and most numerous in the ileum. In the lower part of the jejunum they are small and few in number. They are occasionally seen in the duodenum. These Peyer's patches are the seat of local inflammation and ulceration in typhoid fever.

Function. — It is in the small intestine that the greatest amount of digestion and absorption takes place. The valvulæ conniventes delay the food so that it is more thoroughly subjected to the action of the digestive fluids; and being covered with villi they increase the surface for absorption. The glands of the small intestine secrete the succus entericus which aids in the digestion of food.

THE LARGE, OR THICK, INTESTINE

The largeness of the next division of the alimentary canal is in its width, not in its length; for it is only about five feet (1.5 m.) long, but is wider than the small intestine, being two and one-half inches (6.3 cm.) in its broadest part. It extends from the ileum to the anus. Like the small intestine, it is divided into three parts: the cæcum with the vermiform appendix, colon, and rectum.

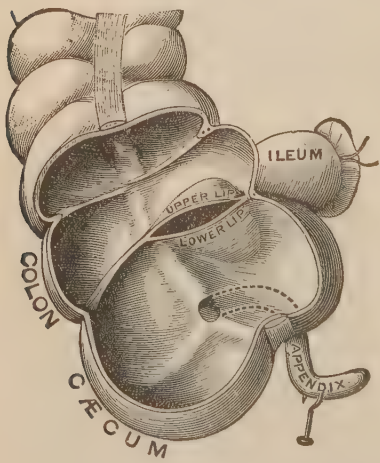


Fig. 173. — Cavity of the Cæcum, its Front Wall Having Been Cut Away. The valve of the colon (ileocæcal) and the opening of the appendix are shown. (Gerrish.)

The cæcum. — The cæcum (*cæcus*, blind) is a large blind pouch at the commencement of the large intestine. The small intestine opens into the side wall of the large intestine about two and a half inches (6.3 cm.) above the commencement of the large intestine. This two and one-half inches of large intestine form a cul-de-sac below the opening, and this cul-de-sac is called the cæcum. The opening from the ileum into the large intestine is provided with two large projecting lips of mucous membrane which allow the passage of material into the large intestine, but effectually prevent

the passage of material in the opposite direction. These mucous folds form what is known as the valve of the colon, or the ileo-cæcal valve.

The **vermiform appendix** is a narrow, wormlike tube about the diameter of an ordinary lead pencil, and from three to seven inches (7.5 to 17.5 cm.) long. It is attached to the lower end of the cæcum, but its directions and relations are very variable. In a general way it may be said to be located in the right iliac region.

The colon. — The colon, though one continuous tube, is subdivided into the *ascending, transverse, and descending* colon, with the sigmoid flexure. The ascending portion ascends on the right side of the abdomen until it reaches the under surface of the liver, where it bends abruptly to the left (right colic or hepatic flexure), and is continued across the abdomen as the transverse colon until, reaching the left side, it curves beneath the lower end of the spleen (left colic or splenic flexure), and passes downward as the descending colon. Reaching the left iliac region on a level with the margin of the crest of the ileum, it makes a curve like the letter S, — hence its name of sigmoid flexure, — and finally ends in the rectum. (See Fig. 166.)

The rectum. — The rectum is from six to eight inches (15 to 20 cm.) long; it passes obliquely from the left until it reaches the middle of the sacrum, then it follows the curve of the sacrum and the coccyx, and finally arches slightly backward to its termination at the anus.

The *anus* is the aperture leading from the rectum to the exterior of the body. It is guarded, and except during defecation is kept closed by the contraction of two involuntary circular muscles called, respectively, the internal and external sphincters.

Coats of the large intestine. — The large intestine has the usual four coats except in some parts where the serous coat only partially covers it, and the rectum, where the serous coat is lacking. The **muscular** coat consists of two layers of fibres, one arranged longitudinally and the other circularly. Beginning at the appendix, the longitudinal fibres are arranged in three ribbon-like bands, which extend the whole length of the colon to the rectum, and these bands being shorter than the rest of the tube, the walls are puckered between them. The third coat consists of **submucous areolar tissue**, and the fourth or inner coat consists of **mucous**

membrane. The mucous coat possesses no villi and no circular folds. It contains numerous tubular glands and solitary lymph nodules which closely resemble those of the small intestine.

Functions. — The functions of the large intestine are three. (1) The process of digestion is continued. This is due to the presence of bacteria, and to the digestive fluids with which the food becomes mixed in the small intestine. (2) The process of absorption is continued, and (3) the waste products are removed from the body.

ACCESSORY ORGANS OF DIGESTION

The accessory organs of digestion are: (1) the salivary glands, (2) the tongue, (3) the teeth, (4) the pancreas, and (5) the liver. The first three have been described.

PANCREAS

The pancreas is an elongated organ, of a pinkish color, which lies in front of the first and second lumbar vertebræ and behind the stomach. It weighs between two and three ounces (60 to 90 grams), is about six inches (15 cm.) long, two inches (5 cm.) wide, and one-half inch (1.25 cm.) thick. In shape it somewhat resembles a hammer, and is divided into head, body, and tail. The right end, or head, is thicker and fills the curve of the duodenum, to which it is firmly attached. The left, free end is the tail, and reaches to the spleen. The intervening portion is the body.

Structure of the pancreas. — It is a compound racemose gland composed of lobules. Each lobule consists of one of the branches of the main duct which terminates in a cluster of saccules that are grape-like in appearance. The lobules are joined together by connective tissue to form lobes, and the lobes, united in the same manner, form the gland. The small ducts from each lobule open into one main duct about the size of a goose-quill, which runs lengthwise through the gland, from the tail to the head. The pancreatic and common bile duct usually enter by means of a common opening into the duodenum about three inches (7.5 cm.) below the pylorus. Sometimes the pancreatic duct and the common bile duct open separately into the duodenum, and there is frequently an accessory duct which opens into the duodenum about an inch above the orifice of the main duct. (See Fig. 174.)

Islands of Langerhans. — Scattered throughout the pancreas are round or ovoid bodies known as the islands of Langerhans. Each island is about one twenty-fifth inch (1 mm.) in diameter and consists of a group of many-sided cells. They are surrounded by

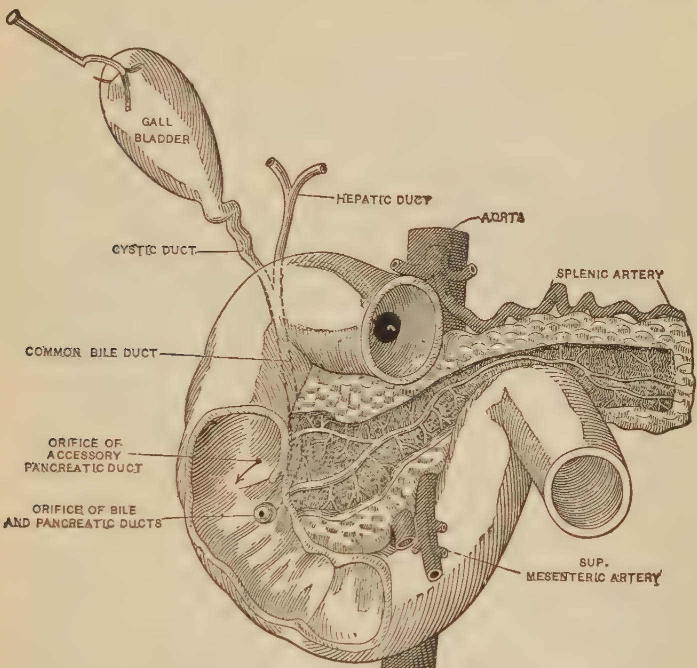


FIG. 174. — DUCTS OF THE PANCREAS. Part of the front wall of the duodenum is cut away. (Gerrish.)

a rich capillary network. Their function is to furnish the internal secretion of the pancreas.

Function. — Two secretions are formed in the pancreas. (1) The pancreatic fluid, which is one of the most important of the digestive fluids, is an external secretion and is poured into the duodenum during intestinal digestion. (2) The secretion formed by the islands of Langerhans is an internal secretion that is absorbed by the blood and carried to the tissues. This internal secretion aids in the oxidation of glucose.

Diabetes mellitus. — This is a disease characterized by a lack of oxidation of glucose and its consequent loss to the body as it is excreted in the urine. The cause is not settled, but it is be-

lieved that disease of the pancreas involving the islands of Langerhans may produce this condition. (See page 337.)

THE LIVER

The liver (hepar) is the largest gland in the body, weighing ordinarily from fifty to sixty ounces (1500 to 1800 grams). It measures eight to nine inches (20 to 22 cm.) from side to side, six to seven inches (15 to 17.5 cm.) from front to back, and four to

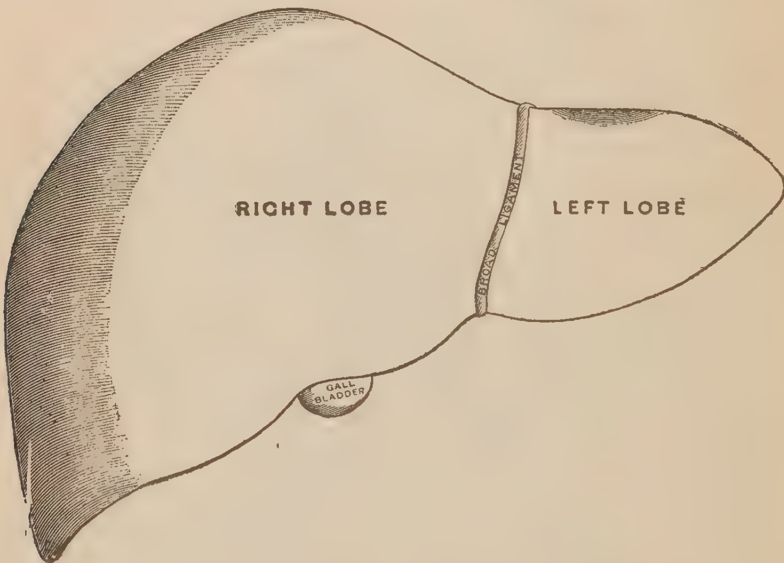


Fig. 175. — The Liver. Front view. (Gerrish.)

five inches (10 to 12 cm.) from above downward in its thickest part. It is a reddish brown organ, placed directly below the diaphragm, in front of the right kidney, the pyloric end of the stomach, and the upper part of the ascending colon. The upper convex surface fits closely into the under surface of the diaphragm. The under concave surface of the organ fits over the right kidney, the upper portion of the ascending colon, and the pyloric end of the stomach. The number *five* prevails in the parts and appendages of the liver.

Ligaments. — The liver is connected to the under surface of the diaphragm, and the anterior walls of the abdomen by five ligaments, four of which are formed by folds of peritoneum, and

the fifth, or round ligament, is a fibrous cord resulting from the atrophy of the umbilical vein of intra-uterine life.

Fissures. — The liver is divided by five fissures into five lobes. The important fissures are (1) the portal, or transverse, which is the gateway for vessels, ducts, and nerves to enter and leave

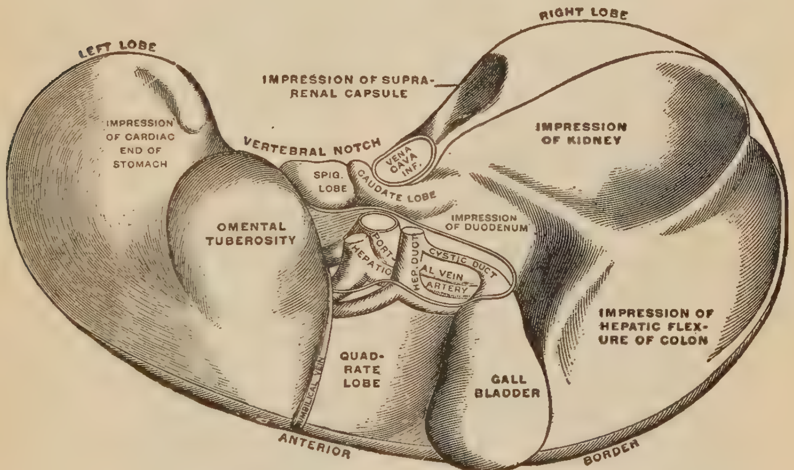


FIG. 176. — THE LIVER. Lower surface. (Gerrish.)

the liver, and (2) the gall-bladder fissure, which supports the gall-bladder. Both these fissures are in the under surface of the liver.

Lobes. — The liver is divided into five lobes: —

1. Right (largest lobe).
2. Left (smaller and wedge-shaped).
3. Quadrate (square).
4. Caudate (tail-like).
5. Spigelian.

Vessels. — The liver has five sets of vessels: —

1. Branches of portal vein.
2. Hepatic veins.
3. Bile ducts.
4. Branches of hepatic artery.
5. Lymphatics.

Minute anatomy of liver. — The liver may be regarded as made up of many minute livers called lobules. Each **lobule** is an irregular body from one-twentieth to one-tenth of an inch (1–2

mm.) in diameter, composed of a multitude of hepatic cells packed so closely together that only enough room is left between them for the passage of blood-vessels, ducts, and nerves. Thus each lobule has all the essentials of a gland; (1) blood-vessels in close connection with secretory cells, (2) cells which are capable of forming a secretion, and (3) ducts by which the secretion is carried away.

The portal vein. — The portal vein brings to the liver venous blood from the stomach, spleen, pancreas, and intestines. After entering the liver, it divides into a vast number of branches

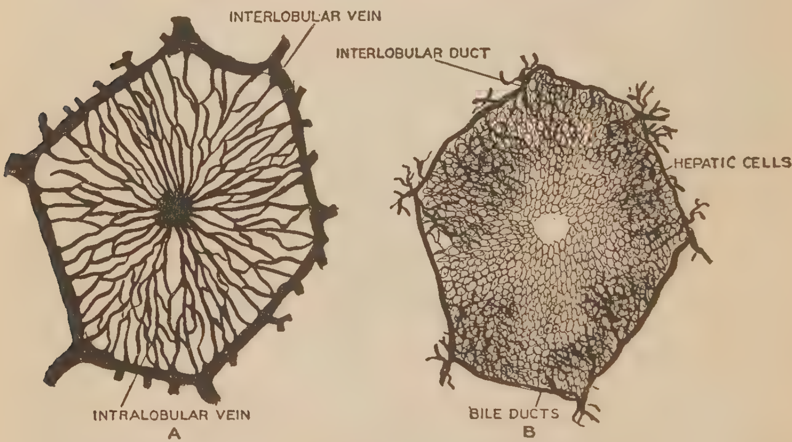


FIG. 177. — DIAGRAMMATIC REPRESENTATION OF TWO HEPATIC LOBULES. *A* shows the interlobular veins running around the outside of the lobule and sending their capillaries into the lobule to join the central vein. In *B*, the bile capillaries are seen with the hepatic cells between them, the bile capillaries radiating to the periphery of the lobule, where they join the interlobular bile ducts.

which form a network surrounding each lobule, and hence are known as **interlobular** (between the lobules) veins. From this network minute capillaries enter the lobule, penetrate between each cell and thus surround them, so that each cell is generously supplied with blood containing the raw material for the manufacture of bile. These capillary branches which enter the lobule and surround the cells are called **intralobular** (within the lobule). These vessels converge toward the centre of the lobule like the spokes of a wheel and empty into a vein (central) which carries the blood away from the lobule. The **central** veins from a number of lobules empty into a much larger vein upon whose surface a vast number of lobules rest,

and therefore the name **sublobular** (under the lobule) is given to these veins. They empty into still larger veins, the **hepatic**, which converge to form three large trunks and empty into the **inferior vena cava**, which is embedded in the posterior surface of the gland.

The bile ducts. — The surfaces of the hepatic cells are grooved, and the grooves on two adjacent cells fit together and form a channel into which the bile is poured as soon as it is formed by the cells. These channels form a network between and around the cells as intricate as the network of blood-vessels. They are called intralobular ducts, and empty into larger ducts called interlobular. These unite and form larger and larger ducts until two main ducts, one from the right and one from the left side of the liver, unite in the portal fissure and form the *hepatic duct*.

FIG. 178. — LOBULE OF RABBIT'S LIVER, VESSELS AND BILE DUCTS INJECTED. *a*, central or intralobular vein; *b*, *b*, interlobular veins; *c*, interlobular bile duct.

The **hepatic duct** runs downward and to the right for about two inches (5 cm.) and then joins at an acute angle the duct from the gall-bladder, termed the *cystic duct*. The hepatic and cystic ducts together form the *common bile duct* (*ductus communis choledochus*), which runs downward for about three inches (7.5 cm.) and enters the duodenum about three inches (7.5 cm.) below the pylorus. This orifice usually serves as a common opening for both the common bile and the pancreatic duct. It is very small and is guarded by a sphincter muscle which keeps it closed except during digestion. (See Fig. 174.)

Hepatic artery. — We must remember that the blood brought to the liver by the portal vein is venous blood and is not intended for purposes of nourishment of the liver itself, hence arterial blood is furnished by the *hepatic artery*. It enters the liver with the portal vein, divides and subdivides in the same manner as the

portal veins, thus forming another network between the lobules, and in the lobules between the cells. The capillaries from the portal vein and the hepatic artery are separate and distinct until, near the centre of each lobule, they unite, and all the blood supplied to the liver by the portal vein and hepatic artery is carried away from it by the hepatic veins which empty into the inferior vena cava.

Lymphatics. — There is a superficial and a deep set. They begin in irregular spaces in the lobules, form networks around the lobules, and run always from the centre outward. They drain off waste products and unconsumed nutritious substances.

Glisson's capsule. — The whole liver is invested in an outer capsule of areolar connective tissue, which is reflected inward at the portal fissure and encloses the vessels and ducts passing through this opening.

Serous membrane. — With the exception of a few small areas, the liver is enclosed in a serous tunic derived from the peritoneum.

Nerves. — Nerves are derived from the left vagus and the solar plexus.[1]

Functions. — The liver may be compared to a wonderful laboratory, the most wonderful in the body. It has three important functions: —

1. *Bile secreting.* — The cells of the liver manufacture bile from the blood brought to them by the portal vein. The function of bile is considered in the next chapter.

2. *Glycogenic.* — The cells of the liver take from the blood brought to them by the portal vein a substance called glucose, which is derived from the carbohydrates of our food. This is stored in the liver in the form of glycogen until such time as the body needs more glucose than the food furnishes. When such demand is made, the liver cells reconvert the glycogen into glucose and pour it into the circulation.

3. *Higher chemical activities.* — Many of the end-products of protein digestion cannot be eliminated until they are acted upon by the liver, and changed into other substances which the kidneys can eliminate, *e.g.*, urea is made from some of these end-products brought to the liver by the blood. It is probable that the liver possesses other important metabolic functions which at pres-

[1] See page 401.

ent are not fully understood. Some physiologists are of the opinion that fibrinogen and antithrombin are formed in the liver.

The gall-bladder. — The gall-bladder is a pear-shaped sac lodged in the gall-bladder fissure on the under surface of the liver, where it is held in place by connective tissue. It is about four inches (10 cm.) long, one inch (2.5 cm.) wide, and holds about ten drachms (40 cc.). It is composed of three coats: (1) the inner one is mucous membrane, (2) the middle one is muscular and fibrous tissue, and (3) the outer one is serous membrane derived from the peritoneum. It is only occasionally that the peritoneum covers more than the under surface of the organ.

Function. — The gall-bladder serves as a reservoir for the bile. During digestion the bile is constantly poured into the intestine; in the intervals it is stored in the gall-bladder.

SUMMARY

J. here.

Digestion. — Digestion is dependent on the proper functioning of certain organs that are grouped together and called the digestive system.

- **Digestive System**
  - **Alimentary canal**
    - Mouth.
    - Pharynx.
    - Œsophagus, or gullet.
    - Stomach.
    - Small or thin intestine
      - Duodenum.
      - Jejunum.
      - Ileum.
    - Large or thick intestine
      - Cæcum.
      - Colon
        - Ascending.
        - Transverse.
        - Descending.
      - Rectum.
  - **Accessory organs**
    - Salivary glands.
    - Tongue.
    - Teeth.
    - Pancreas.
    - Liver.

- **Alimentary Canal**
  - Continuous tube from mouth to anus.
  - About 30 ft. long.
  - From mouth to diaphragm — 3 coats
    - Mucous.
    - Areolar.
    - Muscular.
  - From diaphragm to rectum — 4 coats
    - Mucous.
    - Areolar.
    - Muscular.
    - Serous derived from peritoneum.

- **Mouth, or Buccal Cavity**
  - Above — palate
    1. Hard palate.
    2. Soft palate — uvula, pillars of the fauces, and tonsils.
  - Below — tongue.
  - Front — lips.
  - Sides — cheeks.
  - Contains
    - Tonsils.
    - Tongue.
    - Salivary glands.
    - Teeth.

- **Tonsils**
  - Collections of lymph nodules occupy triangular space between pillars of the fauces on either side of throat.
  - **Function**
    1. May be a source of lymphocytes and leucocytes.
    2. May act as a filter and prevent entrance of microörganisms.

- **Tongue**
  - Special organ of sense of taste.
  - Assists in digestion
    1. Stimulates secretion of digestive fluids.
    2. Assists in swallowing.
    3. Secretes mucus.

- **Salivary Glands**
  - Parotid — just under and in front of ear.
  - Submaxillary, Sublingual — Below the jaw and under the tongue.
  - **Function** — Form a secretion, that mixed with the secretion of the glandular cells of the mouth is called saliva.

- **Teeth**
  - Contained in sockets of alveolar processes of maxillæ and mandible.
  - **Gums** — cover processes and extend into sockets.
  - **Sockets** — lined with periosteum
    - Attaches teeth to sockets.
    - Source of nourishment.
  - 3 portions
    - *Root* — one or more fangs contained in socket.
    - *Crown* — projects beyond level of gums.
    - *Neck* — portion between root and crown.
  - Composed of three substances developed from epithelium
    - *Dentine*
      - Gives shape.
      - Encloses pulp cavity which contains nerves and blood-vessels, that enter by canal from root.
    - *Enamel* — Caps the crown.
    - *Cement* — Covers the root.

Teeth
- 2 sets
  - 1. Temporary — 6 months to 2 yrs.
    - Incisors 8
    - Canines 4
    - Molars 8
    - } 20.
  - 2. Permanent — $6\frac{1}{2}$ yrs. to 21 yrs. of age
    - Incisors 8
    - Canines 4
    - Bicuspids 8
    - Molars 12
    - } 32.
- **Function** — To assist in the process of mastication.

Pharynx
- Cone-shaped tube, 5 inches long, between mouth and œsophagus.
- Muscular, lined with mucous membrane.
- 7 apertures
  - 2 posterior nares.
  - 2 Eustachian tubes.
  - 1 fauces.
  - 1 larynx.
  - 1 œsophagus.

Œsophagus, or Gullet
- Tube — 9 in. long. Extends from pharynx to stomach.
- 3 coats
  - Inner — mucous — disposed in folds.
  - Middle — submucous.
  - Outer — muscular
    - Internal circular layer.
    - External longitudinal layer.
- **Function**
  - 1. Connects the pharynx with the stomach.
  - 2. Receives the food and passes it on to stomach.

Stomach, or Gaster
- Dilated portion of canal, size and shape vary.
- Oblique position in epigastric and left hypochondriac regions under the diaphragm.
- Openings
  - Cardiac orifice — connects with œsophagus.
  - Pyloric orifice — connects with duodenum.
- Curvatures
  - Lesser curvature — concave border.
  - Greater curvature — convex border.
- Parts
  - Fundus — blind end to the left of the heart.
  - Intermediate region — between fundus and pyloric extremity.
  - Pyloric extremity — under the liver.
- 4 coats
  - 1. Outer — serous — peritoneum.
  - 2. Muscular
    - 1. Longitudinal layer.
    - 2. Circular layer.
    - 3. Oblique layer.
  - 3. Submucous — vascular.

- **Stomach, or Gaster**
  - 4 coats
    - 4. Mucous
      - Rugæ
      - Glands
        - Cardiac — secrete mucus.
        - Peptic — chief cells secrete pepsinogen; parietal cells secrete acid.
        - Pyloric — secrete pepsinogen and mucus.
  - Nerves
    - Sympathetic system.
    - Vagi nerves
  - Blood-vessels from cœliac axis.
  - **Functions**
    1. Connects the œsophagus with the intestine.
    2. To hold the food while it undergoes gastric digestion.
    3. To secrete mucus and gastric fluid.

- **Small, or Thin, Intestine**
  - Convoluted tube extends from stomach to valve of colon. Twenty feet, coiled up in abdominal cavity.
  - 3 divisions
    - Duodenum.
    - Jejunum.
    - Ileum.
  - 4 coats
    1. Serous from peritoneum, called mesentery.
    2. Muscular
       - Longitudinal layer.
       - Circular layer.
    3. Submucous
       - Blood-vessels.
       - Lymphatics.
       - Nerves.
    4. Mucous
       - Valvulæ conniventes.
       - Villi — contain lacteals.
  - **Glands and nodes**
    - Simple follicles; Duodenal or Brunner's — Secrete intestinal fluid.
    - Lymph nodules
      - Solitary.
      - Aggregated lymph nodules of Peyer — fifty or more solitary lymph nodules form so-called patches in small intestine.
  - **Function**
    - Digestion.
    - Absorption.
    - Secretion of succus entericus.

Large, or Thick, Intestine

- Largeness in width, not in length.
- Length, 5 ft.; width, $2\frac{1}{2}$ in. to $1\frac{1}{2}$ in.
- Extends from ileum to anus.
- 3 divisions
  - Cæcum, with vermiform appendix.
  - Colon
    - Ascending.
    - Transverse.
    - Descending with sigmoid flexure.
  - Rectum — anus
    - Internal sphincter.
    - External sphincter.
- 4 coats
  - 1. Serous, except that in some parts it is only a partial covering, and at rectum it is wanting.
  - 2. Muscular
    - Longitudinal layer — Arranged in three ribbon-like bands that begin at appendix, and extend to rectum.
    - Circular layer
  - 3. Submucous.
  - 4. Mucous
    - No villi.
    - No valvulæ conniventes.
    - Numerous
      - Tubular glands.
      - Solitary lymph nodules.
- Function
  - Continuance of digestion and absorption.
  - Elimination of waste.

Pancreas

- In front of first and second lumbar vertebræ, behind stomach.
- Hammer shape
  - Head attached to duodenum.
  - Body in front of vertebra.
  - Tail reaches to spleen.
- Size
  - Six inches long.
  - Two inches wide.
  - One-half inch thick.
- Weight — two to three ounces.
- Structure
  - Compound gland — sacculated ends of tubules form lobules.
  - Lobules held together by connective tissue form lobes.
  - Lobes form gland.
  - Duct from each lobule empties into pancreatic duct.
- Function
  - 1. Secretes pancreatic fluid.
  - 2. Forms an internal secretion.

- **Liver**
  - Largest gland in body.
  - Location
    - Right hypochondriac.
    - Epigastric.
    - Left hypochondriac.
  - Convex above — fits under diaphragm.
  - Concave below — fits over right kidney, ascending colon, and pyloric end of stomach.
  - **Five ligaments**
    - 1. Suspensory, broad, or falciform; 2. Coronary; 3. Right lateral; 4. Left lateral — Formed by folds of peritoneum.
    - 5. Round ligament — Results from atrophy of umbilical vein.
  - **Five fissures**
    - 1. Umbilical fissure; 2. Gall-bladder fissure; 3. Portal or transverse fissure — Under surface.
    - 4. Ductus venous fissure; 5. Vena cava — Dorsal surface.
  - **Five lobes**
    - 1. Right (largest lobe).
    - 2. Left (smaller and wedge-shaped).
    - 3. Quadrate (square).
    - 4. Caudate (tail-like).
    - 5. Spigelian.
  - **Five sets of vessels**
    - 1. Branches of portal vein.
    - 2. Bile ducts.
    - 3. Hepatic veins.
    - 4. Branches of hepatic artery.
    - 5. Lymphatics.
  - **Anatomy of liver**
    - Hepatic cells $\frac{1}{1000}$ in. in diameter grouped in lobules.
    - Lobules $\frac{1}{12}$ in. in diameter.
    - Branches of portal vein
      - Interlobular veins (between lobules).
      - Intralobular capillaries (within lobules).
      - Central veins.
      - Sublobular veins (under lobules).
      - Hepatic veins — exit at portal fissure, empty into inferior vena cava.

- **Liver**
  - **Anatomy of liver**
    - Bile ducts
      - Channels between cells (within lobules).
      - Intralobular ducts.
      - Interlobular ducts.
      - Hepatic duct — exit at portal fissure.
    - Branches of hepatic artery
      - Interlobular arteries (between lobules).
      - Intralobular capillaries (within lobules).
      - Course beyond the intralobular capillaries same as that pursued by blood from portal vein.
    - Lymphatics
      - Start in lobules, form network, and run from centre to periphery.
      - Act as drain-pipes.
    - Glisson's capsule encloses the whole of the liver.
    - Serous membrane from the peritoneum almost completely covers it.
  - **Functions**
    - 1. Bile secreting.
    - 2. Glycogenic.
    - 3. Higher chemical activities
      - Changes toxic substances so that they are less harmful and more easily eliminated, *e.g.*, urea.
- **Gall-bladder**
  - Pear-shaped sac lodged in gall-bladder fissure on under surface of liver.
  - Size
    - Four inches long.
    - One inch wide.
    - Capacity about ten drachms.
  - 3 coats
    - 1. Mucous membrane.
    - 2. Fibrous and muscular tissue.
    - 3. Serous membrane from peritoneum.
  - **Function** — Serves as a reservoir for bile.

CHAPTER XV

FOOD. — DIGESTIVE PROCESSES; CHANGES THE FOOD UNDERGOES IN THE MOUTH, STOMACH, SMALL AND LARGE INTESTINES; ABSORPTION

THE process of digestion takes place in the alimentary canal and the purpose of it is to prepare food for absorption and utilization by the tissues of the body. It includes not only the physical process of changing the food to a solution or emulsion, but also the chemical process of *cleavage, i.e.*, the splitting of large and complex molecules into smaller and simpler ones. Both these processes favor diffusion. Of equal significance is the *standardization* of food. Digestion obliterates many of the characteristics which differentiate foods and gives us at last much the same set of products, whatever the meal may have been. From the large number of complex compounds taken into the stomach, only a small number of simple substances are contributed by the intestines to the blood. It is also a process of refining as it separates the useful from the useless residue of our food.

FOOD

Definition. — Food is any substance taken into the body, (1) to provide material for the growth of body tissues, (2) to repair tissue waste, and (3) to supply heat and other kinds of energy.

After birth the material for the growth of the body is derived from our food; also the material to make good the loss resulting from the daily wear and tear of body tissues. All the body activities require a certain amount of energy; this and all the heat dissipated from the body must be supplied by food. The energy in our food is present in the form of potential or latent energy, binding the atoms into molecules, and the molecules into larger masses. The splitting of these complex molecules into smaller and simpler ones releases energy. Food material, over and above

what is needed for this purpose, is stored in the body either in the form of fat, or as glycogen in the liver and muscles. This may be regarded as so much reserve fuel which is oxidized when needed to furnish energy.

Classification of food. — Chemical analysis shows that the elements[1] found in the body are also found in food. Various combinations of these elements give us a great variety of compound substances which are divided into two great classes of nutrients. This division is based on the presence or absence of carbon. Those which contain carbon are organic, those which do not are inorganic. These are further subdivided as follows: —

Nutrients or Food Principles	1. Inorganic	Water.
		Mineral matter or salts.
	2. Organic	Carbohydrates.
		Fats.
		Proteins.

Water. — Water (H_2O) is a very stable compound of hydrogen and oxygen. It enters into the composition of all the tissues, supplies fluid for the body, acts as a solvent for food, and aids in the elimination of waste. Next to air it is the most necessary principle of life and constitutes about two-thirds of the body weight (66 per cent).

Salts. — The principal inorganic salts are: —

Chloride, Phosphate, Sulphate, Carbonate	of sodium and potassium.
Phosphate, Carbonate	of calcium and magnesium.

The inorganic salts are an essential part of all the tissues, and take part in the functions of the body in six ways: (1) they maintain the alkaline or neutral reaction of the fluids of the body; (2) they furnish the material for the acidity or alkalinity of the digestive fluids and other secretions; (3) they help in regulating the flow of fluids to and from the tissues, because they maintain the normal osmotic pressure; (4) they enter largely into the composition of the bones, teeth, and cartilage; (5) they are necessary for the

[1] See page 5.

clotting of blood; and (6) they give the fluids of the body their influence upon the elasticity and irritability of nerve and muscle.

Carbohydrates. — All sugars and starches are grouped under the name of carbohydrates. They contain but three elements, carbon, hydrogen, and oxygen, the two latter in the proportion to form water. The varieties of carbohydrates are as follows: —

Simple or Monosaccharids	Glucose or dextrose, found in fruits, especially the grape, and in the blood. $C_6H_{12}O_6$. Fructose or levulose, found with glucose in fruits. $C_6H_{12}O_6$.	Invert sugar.

Simple sugars. — Simple sugars are one of the standard substances which the tissues can use, and as they are freely soluble and of small molecule they are readily absorbed.

Complex or Disaccharids	Sucrose or cane sugar. $C_{12}H_{22}O_{11}$. Lactose or milk sugar. $C_{12}H_{22}O_{11}$. Maltose or malt sugar. $C_{12}H_{22}O_{11}$.

Complex sugars. — A study of the formulæ of the complex sugars will show that the composition is the same but they are differently named because they give different reactions. Before any of the complex sugars can be utilized in the body they must first be changed either into glucose, or into invert sugar, which consists of a molecule each of glucose and fructose. Only one splitting is necessary as one molecule of a complex sugar plus one molecule of water will form one molecule of glucose and fructose.

$$\overset{\text{Complex Sugar}}{C_{12}H_{22}O_{11}} + \overset{\text{Water}}{H_2O} = \underbrace{\overset{\text{Glucose}}{C_6H_{12}O_6} \cdot \overset{\text{Fructose}}{C_6H_{12}O_6}}_{\text{Invert Sugar}}$$

Polysaccharids	Starch — found in grain, tubers, roots, etc.	$(C_6H_{10}O_5)n$
	Cellulose — outside covering of starch grains, and basis of all woody fibres.	$(C_6H_{10}O_5)n$
	Glycogen — form in which sugar is stored in the liver and muscles.	$(C_6H_{10}O_5)n$
	Dextrin — formed from starch by partial hydrolysis.	$(C_6H_{10}O_5)n$

Polysaccharids. — In all of these compounds the composition of the molecule is supposed to be rather complex, although the

elements are present in the same relative proportion, as shown in the formulæ. The value of n, however, may be very small or very large and is probably different for each polysaccharid, which makes the actual composition of each member of the group different. For instance, n for the starch molecule is large, while for the dextrin molecule it is smaller, so that a single starch molecule in digestion may split into several molecules of dextrin of the same relative composition. In the disaccharids only one splitting is necessary, as each molecule of a complex sugar plus one molecule of water will give two molecules of a simple sugar. As polysaccharids are so complex, they must pass through several stages before they are changed by hydrolytic cleavage to a simple sugar. Each splitting of the molecule gives substances with simpler composition, though with the same relative proportion of the constituents, and to each is given a special name. Thus as the result of the first splitting we have dextrin, of which there are three varieties, *i.e.*, erythrodextrin, achroödextrin, and maltodextrin, each one being produced as a result of the further splitting of the molecules; then maltose, a disaccharid, is yielded, and finally glucose, a monosaccharid or simple sugar. The number of molecules of simple sugar resulting from the hydrolysis of any polysaccharid would depend upon the value of n.

Fats. — Fats are composed of carbon, hydrogen, and oxygen, but the hydrogen content is relatively high. The ordinary fats of animal and vegetable food are not simple substances, but are mixtures of simple fats named palmitin, stearin, and olein, which are derived from the fatty acids, palmitic, stearic, and oleic. Each molecule of a simple fat is made from one molecule of glycerine and three molecules of a fatty acid. This reaction is comparable to the neutralization of an acid by a base resulting in a salt and water. (See page 8.)

$$\begin{array}{ccccccc} \text{Acid} & + & \text{Base} & \rightarrow & \text{Salt} & + & \text{Water} \\ HCl & + & NaOH & \rightarrow & NaCl & + & H_2O \end{array}$$

$$\begin{array}{ccccccc} \underset{\text{(STEARIC ACID)}}{\text{Acid}} & + & \underset{\text{(GLYCERINE)}}{\text{Base}} & \rightarrow & \underset{\text{(STEARIN)}}{\text{Salt}} & + & \underset{\text{(WATER)}}{\text{Water}} \\ 3\,H \cdot C_{18}H_{35}O_2 & + & C_3H_5(OH)_3 & \rightarrow & C_3H_5(C_{18}H_{35}O_2)_3 & + & 3\,H_2O \end{array}$$

In general, fats and oils are practically the same, and the mixture of fats found in the body is liquid at the body temperature. They are soluble in ether, chloroform, and hot alcohol, but are insoluble in water. Under the influence of steam, mineral acids, and certain enzymes found in the body, fats split up into the substances of which they are built, *i.e.*, glycerine and fatty acids. Accordingly, the digestion of fats is a reaction in exactly the opposite direction from the one above.

$$\underset{\text{(STEARIN)}}{\text{Salt}} + \underset{\text{(WATER)}}{\text{Water}} \rightarrow \underset{\text{(GLYCERINE)}}{\text{Base}} + \underset{\text{(STEARIC ACID)}}{\text{Acid}}$$

$$C_3H_5(C_{18}H_{35}O_2)_3 + 3\ H_2O \rightarrow C_3H_5(OH)_3 + 3\ H.C_{18}H_{35}O_2$$

The process of *saponification* is similar to the above, only that instead of water a base is used and the final products are glycerine and soap.

$$\underset{\text{(STEARIN)}}{\text{Salt}} + \underset{\text{(POTASSIUM HYDROXIDE)}}{\text{Base}} \rightarrow \underset{\text{(GLYCERINE)}}{\text{Base}} + \underset{\text{(SOAP)}}{\text{Soap}}$$

$$C_3H_5(C_{18}H_{35}O_2)_3 + 3\ KOH \rightarrow C_3H_5(OH)_3 + 3\ K(C_{18}H_{35}O_2).$$

Proteins. — Proteins consist of carbon, hydrogen, nitrogen, oxygen; sulphur, phosphorus, and other elements may be present. They are more complex than either carbohydrates or fats and differ from them in having *nitrogen*, hence they are described as nitrogenous compounds. Proteins are difficult to analyze but modern chemists have shown that they are built up of simpler substances called amino-acids. Accordingly, the digestion of proteins which is a process of hydrolysis means reducing them to amino-acids, and the number of stages through which they pass depends upon the size [1] and the complexity of the molecule. Each splitting of the molecule gives substances with simpler composition and to each such substance is given a special name, *i.e.*, → Protein → Metaprotein → Proteoses → Peptones → Peptids → Amino-acids. The number of molecules of amino-acids resulting from the hydrolysis of any protein would depend upon the size of the molecule.

About twenty amino-acids have been described, and are sometimes compared to the letters of the alphabet. Various combinations of letters result in an enormous number of words. In a similar way various combinations of amino-acids result in many

[1] The large size of the protein molecule can be judged by the empirical formula assigned to globin, one of the simplest forms: $C_{700}H_{1098}N_{184}S_2O_{196}$.

different kinds of proteins which give different reactions and are represented by different formulæ.

Classification of proteins. — For experimental purposes proteins have been classified as shown below; the classification being based on their solubility in various reagents and on other reactions.

- **Proteins**
  - Simple
    - Albumins.
    - Globulins.
    - Glutelins.
    - Alcohol-soluble proteins (prolamines).
    - Albuminoids.
    - Histons.
    - Protamins.
  - Conjugated
    - Nucleoproteins.
    - Glycoproteins.
    - Phosphoproteins.
    - Hæmoglobins.
    - Lecithoproteins.
  - Derived
    - Primary derivatives (formed through hydrolytic changes which cause only slight alterations of the protein molecule)
      - Proteans.
      - Metaproteins.
      - Coagulated proteins.
    - Secondary derivatives (products of further hydrolytic cleavage of the protein molecule)
      - Proteoses.
      - Peptones.
      - Peptids.

In this classification the group called *simple proteins* hydrolyze to amino-acids, *conjugated proteins* yield amino-acids and some other body. This latter substance is nuclein in the nucleoproteins, a carbohydrate in the glycoproteins, a phospho body in the phosphoproteins, hæmatin in hæmoglobins, and a fatty substance in lecithoproteins. The *derived proteins* are changed forms produced by the action of heat, acids, alkalies, or enzymes.

Accessory articles of diet. — In addition to the foodstuffs proper, our foods contain numerous other substances which in one way or another are useful in nutrition, although not absolutely necessary. These substances, differing in nature and importance, may be classified under the three heads of: —

Flavors: The various oils or esters that give odor and taste to foods.
Condiments: Salt, pepper, mustard, etc.
Stimulants: Tea, coffee, cocoa, meat extracts, etc.

DIGESTIVE PROCESSES

In a broad sense all the processes by which foods are rendered available to an organism are digestive processes. The word alimentation is often used to include the preparatory processes together with the digestive processes. In this sense, many industrial and domestic processes are in line with digestion and often initiate the task which the digestive organs complete. This is particularly true of cooking, for by it various chemical changes are brought to pass; such, for example, as changing starches into dextrins, partially splitting fats into glycerine and fatty acids, and changing some proteins to the first stages of their decomposition products. A second reason for classifying cooking as a digestive process is that the appearance, odor, and taste of food are improved, and these facts stimulate the end organs of the special senses, causing a reflex stimulation of the digestive mechanisms. In a third way cooking may profoundly aid digestion by killing parasites or bacteria which otherwise would gain a foothold in the alimentary canal and thus modify or change digestive processes. It is usual to describe digestion within the body as consisting of two processes, *i.e.*, mechanical and chemical.

Both the mechanical and chemical processes of digestion are controlled by the nervous system. Any severe strain or strong emotion which affects the nervous system unpleasantly, inhibits the secretion of the digestive fluids and interferes with digestion, often checking the appetite and even preventing the taking of food. On the other hand, pleasurable sensations aid digestion, hence the value of attractively served food, pleasant surroundings, and cheerful conversation.

Mechanical digestion. — Mechanical digestion is effected by various physical processes that occur in the alimentary canal. It is to be considered as preliminary to the more important chemical digestion. It serves four important purposes: (1) in taking food in and moving it along through the alimentary canal just rapidly enough to allow the required chemical changes to take place in each part; (2) in lubricating the food by adding the mucin and water secreted by the glands of the alimentary canal; (3) in liquefying the food by mixing it with the various digestive fluids; and (4) in separating the food into small particles, thereby increasing

the amount of surface to come in contact with the digestive fluids.

The mechanical processes consist of: —

1. Mastication.
2. Deglutition or swallowing.
3. Peristaltic action of œsophagus.
4. Movements of the stomach.
5. Movements of the intestines.
6. Defecation.

Chemical digestion. — The most essential part of digestion is chemical and is a process of hydrolytic cleavage which is dependent upon the presence of enzymes. The term hydrolysis means the breaking down of complex molecules into simpler ones with the absorption of water. An example of hydrolysis is the conversion of any of the complex sugars into simpler sugars. (See page 306.)

Necessity for chemical digestion. — Chemical digestion is necessary because organic foods, with the exception of simple sugars, cannot diffuse through animal membranes, and even if diffusion were possible, the tissues could not use them, hence they must be reduced to smaller molecules and to such standard substances as the tissues can use, *i.e.*, (1) simple sugars, resulting from the digestion of all carbohydrate foods; (2) glycerine and fatty acids, resulting from the digestion of fats; and (3) amino-acids, resulting from the digestion of proteins.

Cause of chemical digestion. — It is possible to make carbohydrates, fats, and proteins undergo the same changes outside the body as occur during digestion. Carbohydrates, fats, and proteins, if boiled with a mineral acid or subjected to the action of enzymes, will hydrolyze and split up into simpler substances. Within the body these changes take place at body temperature, and are due to the enzymes present in all of the digestive fluids.

Enzymes. — The exact composition of enzymes is not known. One author suggests the following definition: "An enzyme is a substance produced by living cells which acts by catalysis." In other words, they are organic substances which vary (hasten or retard) the speed of reactions, but do not initiate them. Their efficacy is destroyed by boiling. The following characteristics may be noted: —

Optimum temperature. — The body enzymes act best at the temperature of the body. They are destroyed by a high temperature and their effect is retarded wholly or in part by a low temperature.

Medium. — Each enzyme requires a medium of definite reaction either acid, alkaline, or neutral. The enzyme of saliva requires an alkaline or neutral medium, while the enzymes of the gastric fluid require an acid medium.

Active and inactive form. — It has been demonstrated that an enzyme may exist within the cell producing it in an antecedent or inactive form which is designated as a *zymogen.* The zymogen may be stored in the cell in the form of granules which are converted into active enzyme at the moment of secretion, or it may be secreted in inactive form and require the coöperation of some other substance before it is capable of effecting its normal reaction. In such cases the second substance is said to activate the enzyme. An example is found in the case of the enterokinase which activates the trypsinogen of the pancreatic secretion. (See page 321.)

Coenzymes. — There are some cases where the action of an enzyme is helped by, or even dependent upon the presence of some other substance. A good example of this activity is furnished by the influence of bile-salts upon lipase.[1] These cases of *coactivity* are to be distinguished from activation, by the fact that the combination may be made or unmade. For example, in a mixture of bile salts and lipase, the bile salts may be removed by dialysis. In activation, on the contrary, the active enzyme cannot be changed back to the inactive zymogen.

Classification of enzymes. — There is no consensus of opinion among physiologists or chemists as to the system to be followed in naming or classifying enzymes. Recently it has been suggested that an enzyme be designated by the name of the substance on which it acts, and that all of them be given the termination *ase.* According to this system the enzyme acting on starch would be amylase; that on maltose, maltase; that on fat, lipase. This suggestion has been followed in part only, as the older enzymes are still most frequently referred to under their original names. The following classification is a modification from a standard physiology:[2] —

[1] See page 322. [2] Howell's "Text-book of Physiology," sixth edition.

1. The sugar-splitting enzymes. These fall into two subgroups: (*a*) The inverting enzymes, which convert the double sugars or disaccharids into the monosaccharids. Examples: Maltase, which splits maltose to dextrose; invertase, which splits cane-sugar to dextrose and levulose; and lactase, which splits milk-sugar (lactose) to dextrose and galactose. (*b*) The enzymes, which split the monosaccharids. There is evidence of the presence in the tissues of an enzyme capable of splitting the sugar of the blood and tissues (glucose) into lactic acid.

2. The amylolytic or starch-splitting enzymes. Examples: Ptyalin or salivary diastase, amylase, or pancreatic diastase. They cause a hydrolytic cleavage of the starch molecule.

3. The lipolytic, or fat-splitting enzymes. Example: The lipase found in the pancreatic secretion, in the liver, connective tissues, blood, etc. They cause a hydrolytic cleavage of the fat molecule.

4. The proteolytic or protein-splitting enzymes. Examples: Pepsin of gastric fluid, trypsin of pancreatic fluid. They cause a hydrolytic cleavage of the protein molecule.

5. The clotting enzymes, which convert soluble to insoluble proteins. Example: The clotting of the casein of milk by rennin.

6. The oxidizing enzymes, or oxidases. A group of enzymes which set up oxidation processes. Opinions differ in regard to the manner in which these enzymes act.

7. The deaminizing enzymes. All amino-acids contain an NH_2 group which is split off by hydrolytic cleavage and is converted to ammonia $\rightarrow$ NH_3, and then probably to urea $\rightarrow$ $NH_2—CO—NH_2$. See page 339.

CHANGES THE FOOD UNDERGOES IN THE MOUTH

Mastication. — When solid food is taken into the mouth it is cut and ground by the teeth, being pushed between them again and again by the muscular contractions of the cheeks, and the movements of the tongue, until the whole is thoroughly crushed and ground down, thus exposing a larger surface to the action of the digestive fluids.

Insalivation. — During the process of mastication saliva is poured in large quantities into the mouth, and mixing with the food, lubricates, moistens, and reduces it to a soft, pulpy condition. A certain amount of air caught in the bubbles of the saliva also becomes entangled in the food, and this facilitates the penetration of the gastric fluid.

Secretion of saliva. — The secretion of saliva is the result of reflex stimulation of the nerves connected with the salivary glands. This is a psychical reflex which is initiated by the sight, thought, or

smell of food, acting as stimulants to the sensory or afferent nerves which carry these impulses to a nerve centre in the brain (probably in the medulla oblongata), and from thence motor impulses are transmitted through efferent nerves to the gland. The movements of mastication and the taste of food continue this stimulation, so that the secretion is continued till the end of the meal.

Saliva. — Saliva is a mixture of the secretions of all three pairs of salivary glands, as well as of the small glands of the mucous membrane of the mouth. It consists of water, some mucin, and an enzyme called *ptyalin* or salivary diastase. It has a specific gravity of 1.004 to 1.008 and an alkaline reaction when tested with litmus paper. The amount secreted in twenty-four hours is estimated to be from one to two quarts (1–2 litres).

The functions of saliva. — Saliva has four distinct functions: (1) by softening and moistening the food it assists in mastication and deglutition; (2) by coating the food with mucin it lubricates it and insures a smooth passage along the œsophagus; (3) by dissolving dry and solid food it provides a necessary step in the process of stimulating the taste nerves, and taste sensations play an important part in the secretion of gastric fluid; (4) by virtue of the enzyme which it contains it changes starch to simpler substances, *i.e.*, dextrin and maltose.

Ptyalin or salivary diastase. — By the action of the enzyme ptyalin which is present in saliva, starch is partially changed to dextrin and maltose. This process is a complicated one consisting of a series of hydrolytic changes which take place in successive stages, and result in a number of intermediate compounds. The change is best effected at the temperature of the body,[1] in a slightly alkaline solution, saliva that is distinctly acid hindering or arresting the process. Boiled starch is changed more rapidly and completely than raw, but food is rarely retained in the mouth long enough for the saliva to more than begin the transformation of starch.

Deglutition or swallowing. — The softened and moistened food is brought together on the upper surface of the tongue and pressed backward through the fauces into the pharynx. Then the muscular bands in the wall of the pharynx contract and force the food into

[1] A temperature of 100° F. in the alimentary canal is necessary for digestion, hence iced drinks or iced foods that lower this temperature delay digestion.

the œsophagus. At this moment breathing has to be suspended and the passages closed against the possible entrance of food. The soft palate is drawn back, thus protecting the nasal passages, and the larynx is shielded by being pulled forward under the root of the tongue, and has an additional safeguard through the folding down upon it of the epiglottis. When food is once within the œsophagus, breathing may be resumed and the downward passage of the food is assisted by the peristaltic action of the œsophagus.

When liquids are swallowed they are shot down the œsophagus by the initial act of swallowing, and may find the cardiac orifice closed. In this case, the liquid is held until the peristaltic wave reaches the cardiac orifice, when the tissues relax and allow the liquid to pass.

Peristalsis. — Peristalsis occurs in such tubular viscera as the œsophagus, stomach, intestines, etc., which possess muscular coats. Peristalsis consists of a series of wave-like contractions of the circular fibres which affect successive portions of the tube from above downward. The constricted portion is always preceded by an area of relaxation, which renders the contraction more effective in forcing the contents onward. The direction is always the same, and the action is under the control of the nervous system.

Summary. — During the process of mastication, insalivation, and deglutition the food is first reduced to a soft, pulpy condition; second, any starch it may contain begins to be changed into sugar; third, it acquires a more or less alkaline reaction.

Vomiting. — Under ordinary circumstances the contractions of the cardiac sphincter muscle prevent the regurgitation of food, but strong contractions of the stomach or spasmodic contractions of the abdominal muscles may, if the diaphragm is fixed, force the contents of the stomach through the œsophagus and mouth to the exterior. This is called vomiting.

CHANGES THE FOOD UNDERGOES IN THE STOMACH, OR STOMACH DIGESTION

The food which enters the stomach is delayed there by the contraction of the sphincter muscles at the cardiac and pyloric openings. The cavity of the stomach is always the size of its contents, which means that when it is empty it is contracted, but when food enters, it expands just enough to hold it. Within a

few minutes after the entrance of food small contractions start in the middle region of the stomach and run toward the pylorus. These contractions are regular and become more and more forcible as digestion progresses. As a result of these movements the food is macerated, mixed with the acid gastric fluid, and reduced to a thin liquid mass called **chyme**. At certain intervals the pyloric sphincter relaxes and the wave of contraction forces some of the chyme into the duodenum. The fundal end of the stomach does not take part in these movements, but serves as a reservoir for food which is under slight pressure, as the muscles are in a state of continual contraction or tone. Due to the lack of movement and the muscular tone, the gastric fluid cannot penetrate the bolus of food, and the ptyalin with which it became mixed in the mouth continues its action, and the digestion of starch continues for about half an hour. As the chyme is gradually forced into the duodenum, the pressure of the fundus forces the food into the pyloric end.

The stomach is admirably adapted to receive a large amount of food within a short period of time. It reduces this food to chyme, and at intervals charges the intestine with small amounts of this chyme in such condition as to admit of rapid digestion. It seems probable that without the stomach, our mode of eating would have to be changed, as it would not be possible to load the intestine with the amount of food ordinarily consumed at a meal.

Time required for stomach digestion. — It is obvious that the time required for gastric digestion depends upon the nature of the food eaten. An average meal of mixed food requires about five hours for gastric digestion. The ejection of chyme through the pylorus occurs at regular intervals, and is supposed to depend upon the consistency and acidity of the chyme. Solid particles forced against the pylorus tend to keep it closed, but hydrochloric acid in the stomach seems to favor or produce relaxation of the pyloric sphincter. In the intestines hydrochloric acid has a contrary effect, as it causes a contraction of the sphincter, which remains closed after each ejection until the acidity has been neutralized.

Secretion of gastric fluid. — The secretion of gastric fluid seems to begin in advance of the actual arrival of food in the stomach, and to be in proportion to the pleasure of the meal. It continues as long as food remains in the stomach, and is caused

and maintained by two factors: (1) *psychical,* the sensations of eating; the taste and odor of food stimulate the sensory nerves situated in the mouth and nose. These afferent impulses are transferred through nerve centres to efferent fibres of the vagus nerve, and thus are carried to the stomach. (2) *Chemical,* (*a*) by secretogogues contained in certain foods and (*b*) by secretogogues contained in the products of digestion. Certain foods, such as meat juices and extracts, contain substances called secretogogues or hormones which are supposed to act directly upon the nerves of the pyloric mucous membrane and form a substance called *gastrin* or *gastric secretin,* which is absorbed into the blood and carried to the gastric glands. This substance stimulates the glands to secretion. Other foods, such as milk, bread, white of egg, etc., do not appear to contain secretogogues. When such foods are eaten, a psychical secretion is started and when this has acted, some products of their digestion in turn become capable of stimulating a further secretion of gastric fluid.

Gastric fluid. — Gastric fluid is secreted by the gastric glands[1] lining the mucous membrane of the stomach. It is a thin, colorless, or nearly colorless liquid with a strong acid reaction, and a specific gravity of about 1.002–1.003. The quantity secreted depends upon the amount of food to be digested. Upon analysis it is found to contain some protein, some mucin, and inorganic salts, but the essential constituents are hydrochloric acid and two or possibly three enzymes, pepsin, rennin, and lipase.

Hydrochloric acid. — It is generally believed that the parietal cells of the gastric glands secrete the hydrochloric acid, from chlorides found in the blood. The chief chloride is sodium chloride ($NaCl$), and by some means this is decomposed; the chlorine (Cl) combines with hydrogen (H), and is then secreted upon the free surface of the stomach as hydrochloric acid (HCl). In normal gastric fluid it is found in the proportion of 0.2 to 0.4 per cent. It serves (1) to activate pepsinogen and convert it to pepsin; (2) provides an acid medium which is necessary for the pepsin to carry on its work; (3) swells the protein fibres, thus giving easier access to pepsin; (4) it helps in the inversion of sugar, *i.e.,* changing complex sugars to simple ones; (5) it acts as a disinfectant

[1] See page 282.

and kills many bacteria that enter the stomach, and (6) it helps to regulate the opening and closing of the pyloric valve.

Pepsin. — Pepsin is supposed to be formed in the pyloric glands and the chief cells of the gastric glands. It is present in these cells in the form of a zymogen, an antecedent inactive substance called pepsinogen which is quickly changed to active pepsin by the action of hydrochloric acid.

Pepsin is a weak proteolytic enzyme requiring an acid medium in which to work. It has the property of converting more or less of the protein of the food into simpler and more soluble proteoses and peptones. This action is preparatory to the more complete hydrolysis that takes place in the intestines under the influence of trypsin and erepsin, for peptones are not absorbed but suffer a further hydrolysis to amino-acids.

Rennin. — Rennin, like pepsin, is supposed to be formed in the chief cells of the gastric glands in a zymogen form, the *prorennin* which after secretion is converted to the active enzyme. So far as is known, this enzyme acts *only* upon the soluble protein of milk, which is called *caseinogen.* It converts this substance into a clotted mass called curd; the digestion of which is carried on by the pepsin, and later in the intestine by the trypsin.

Various observers have described other enzymes in addition to the pepsin and rennin, but the evidence regarding these is uncertain. It is probable that the ptyalin swallowed with the food continues the digestion of starchy material in the fundus for some time. Regarding the fats, it is believed that they undergo no true digestive change in the stomach. They are set free from their mixture with other foodstuffs by the dissolving action of the gastric fluid; they are liquefied by the heat of the body, and are scattered through the chyme in a coarse emulsion by the movements of the stomach, all of which favors the subsequent action of the pancreatic fluid. Emulsified fats like cream are acted upon to a limited extent by a third enzyme called *gastric lipase,* and this action may be important in the digestion of milk fat by infants, as the pancreas is inactive.

Summary. — The stomach serves as a place for storage and maintains a gradual delivery to the intestine. The movements are adapted to promote the mechanical reduction of food. Salivary digestion of starch continues until the acidity is everywhere

established. Gastric digestion affects proteins chiefly and is incomplete. There is some digestion of emulsified fat.

CHANGES THE FOOD UNDERGOES IN THE SMALL INTESTINE

The chyme, entering the duodenum, after an ordinary meal, is a mixture of various matters. It probably contains proteoses and peptones derived from the proteins; dextrins and sugar from the carbohydrates; traces of glycerine and fatty acids from the fats; portions of all the foods not yet digested; hydrochloric acid from the gastric fluid; and lactic acid produced by fermentation. It is in the intestines that this mixture undergoes the most profound digestive changes. These changes which constitute intestinal digestion are effected by: (1) the movements of the intestines, (2) the pancreatic fluid, (3) the succus entericus or secretion of the intestinal glands, and (4) the bile.

Movements of the small intestine. — The movements of the small intestine are of two kinds: (1) peristaltic and (2) pendular or rhythmic segmentation.

(1) A peristaltic movement may be defined as a quick succession of waves of contraction and inhibition passing slowly along the intestine. The wave of contraction begins at a certain point, passes downward away from the stomach, and is always preceded by an area of inhibition or relaxation. The purpose of it is to pass the food slowly forward, and it is obvious that the wave of contraction is more effective in forcing the contents forward because just in front of it the intestine is relaxed.

(2) The movements of pendular or rhythmic segmentation consist of local constrictions of the intestinal wall which occur rhythmically at points where masses of food lie. The purpose of these constrictions is to divide the string of food into a number of equal segments. Within a few seconds each of these segments is halved and the corresponding halves of adjoining segments unite. Again constrictions recur and these newly formed segments are divided, and the halves reform in the same position as they had at first. In this way every particle of food is brought into intimate contact with the valvulæ conniventes and is thoroughly mixed with the digestive fluids.

Secretion of pancreatic fluid. — Just as the chewing and swallowing of food starts the gastric secretion, so the presence of acid chyme in the intestine starts the pancreatic secretion. This effect is due to a special substance called *secretin* which is formed by the action of the acid upon a substance called prosecretin which is present in the mucous membrane of the intestine. This secretin is absorbed by the blood and carried to the pancreas, which it stimulates to activity. (See page 322.)

Pancreatic fluid. — Healthy pancreatic fluid is a clear, somewhat viscid fluid, with a very decided alkaline reaction. The amount secreted in twenty-four hours is about one to one and two-thirds pints (500 to 800 cc.). It contains few solids and is dependent for its remarkable power on three enzymes: (1) trypsin, (2) pancreatic diastase (amylase), and (3) lipase (steapsin). Some authors state that the secretion contains a fourth enzyme, *i.e.*, rennin.

Action of pancreatic fluid upon food. — Pancreatic fluid has the power of acting on all the foodstuffs, proteins, carbohydrates, and fats. This action is due to its enzymes.

(1) *Trypsin.* — Trypsin is secreted in the form of a zymogen called trypsinogen, and is activated by enterokinase, an enzyme which is contained in the mucous membrane of the small intestine. Trypsin, like pepsin, causes hydrolytic cleavage of proteins, but the action is more rapid and powerful, and the protein molecule is broken up into simpler substances than peptones, depending on the amount of trypsin and the time that it acts. If complete hydrolysis takes place, the end-products consist chiefly of amino-acids. Trypsin attacks proteins in slightly acid, neutral, or strongly alkaline mediums. The preliminary action of pepsin, on a protein molecule, hastens the action of trypsin, and renders it more complete than if the trypsin acted alone.

(2) *Diastase* (*Amylase*). — The action of diastase is similar to that of ptyalin. It causes hydrolysis of starch with the production of achroödextrin and maltose. The starchy food that escapes digestion in the mouth and stomach becomes mixed with this enzyme and continues under its action until the ileo-cæcal valve is reached. Before absorption, achroödextrin and maltose are further acted upon by the maltase of the intestinal secretion and converted to dextrose.

(3) *Lipase* (*Steapsin*). — Lipase is an enzyme capable of hydrolyzing fats to glycerine and fatty acids. The process of hydrolysis is preceded by the mechanical process of emulsification which results in tiny droplets of fat. This increases the surface of fat exposed to the chemical action of the lipase and from a physiological standpoint is regarded as a preparatory process. Glycerine and fatty acids are absorbed by the epithelium of the intestine, and again combine to form fat. It is probable that in this synthesis the fatty acids combine with the glycerine in such proportions as to make the kind of fat characteristic of the animal. The action of lipase is said to be reversible, *i.e.*, it causes both the splitting of the fats and the synthesis of the split products, not only in the intestines, but in the various tissues, during the metabolism or the storage of fat. Lipase is found in blood and in many tissues, — muscle, liver, mammary glands, etc.

There is a possibility that the fat (salt) may combine with an alkali (base) and form soap. This reaction is known as saponification. It is difficult to say how far it usually goes on.

Succus entericus, or intestinal fluid. — Succus entericus is the secretion of the intestinal glands. It is a clear, yellowish fluid, having a marked alkaline reaction and containing a certain quantity of mucin. There is much disagreement as to the properties and importance of this secretion. It is said to have little or no digestive action except upon starches; nevertheless, the general tendency is to attribute to it, plus the intracellular enzymes, a larger share in the work of digestion than was formerly granted. These intracellular or endo-enzymes are not secreted into the lumen of the intestine but are held within the cells, and strictly speaking, are not a constituent of the intestinal fluid. However, it is their action on food that is the important contribution of the intestinal glands to digestion. These enzymes and their actions are as follows: —

Enterokinase. — This enzyme activates the trypsinogen of pancreatic fluid and converts it into trypsin.

Erepsin. — This enzyme hydrolyzes proteoses and peptones to amino-acids, thus completing the work begun by the pepsin and trypsin. It is claimed that it occurs not only in the intestinal mucosa but also in the liver, kidney, pancreas, and possibly in other tissues.

Inverting enzymes. — These enzymes are three in number and convert disaccharids into monosaccharids.

1. Maltase acts upon the products formed in the digestion of starches, *i.e.*, dextrin and maltose, and converts them to dextrose.

2. Invertase or sucrase acts upon sucrose and changes it to dextrose and levulose.

3. Lactase acts upon lactose and changes it to dextrose and galactose.

This inverting action is necessary because double sugars cannot be used by the tissues and would escape in the urine, but in the form of simple sugars they are readily used by the tissues.

Secretin. — This is not an enzyme, but a hormone, and plays an important part in the control of the secretion of the pancreas. It is secreted or formed in the intestinal mucosa in a preliminary form called prosecretin, and under the influence of acid is changed to secretin. Secretin is absorbed and carried to the pancreas, which it stimulates to activity.

Bile. — Bile is a fluid of a golden brown or greenish color[1] with an alkaline reaction. It is secreted continuously by the liver, but only enters the duodenum during the period of digestion. During the intervening period it is prevented from entering the duodenum by the sphincter which closes the common bile duct, and consequently backs up into the gall-bladder. Apparently the ejection of chyme into the duodenum excites a contraction of the gall-bladder and an inhibition of the sphincter which results in an ejection of bile. The quantity secreted in twenty-four hours varies with the amount of food taken, but is estimated at about one to one and two-thirds pints (500 to 800 cc.). Bile contains no enzymes, but serves as a coenzyme and activates the lipase of the pancreatic fluid. Its physiological effects may be grouped as follows: —

1. *Digestive secretion.* — It serves as a digestive secretion by accelerating the action of the lipase of the pancreatic fluid in splitting fats to glycerine and fatty acids, and aids in the absorption of these products.

2. *Excretion.* — Its value as an excretion we know little about,

[1] The color of bile is determined by the respective amounts of the bile pigments: (1) biliverdin, and (2) bilirubin, that are present.

but it is thought to serve as a channel by which the products of the disintegration of hæmoglobin are carried from the body.

3. *Antiseptic.* — It has a feeble and questioned antiseptic action upon the intestinal contents, and its presence limits putrefaction to some extent.

Action of bacteria in small intestine. — Numerous bacteria which are able to hydrolyze carbohydrates and proteins are constantly present in the small intestine. Fermentation of the carbohydrates gives rise to organic acids, such as lactic and acetic, but none of the products of this fermentation are considered toxic. On the other hand, the putrefaction of proteins gives rise to a number of end-products that are distinctly toxic. Under normal conditions and on a mixed diet, carbohydrate fermentation is the characteristic action of the bacteria in the small intestine; while protein putrefaction occurs in the large intestine. The reason for this seems to be that carbohydrates serve to protect proteins because some of the bacteria of the small intestine, *i.e.*, bacillus coli, will not attack proteins as long as carbohydrate material is present. In addition, the organic acids produced by the fermentation of carbohydrates tend to neutralize the alkalinity of the intestinal secretion, and may even give an acid reaction. An acid reaction is unfavorable to the action of the bacteria that hydrolyze proteins, and in this way putrefaction in the small intestine is prevented. From this it follows that the nature of bacterial activity in the small intestine depends upon the character of the diet, which may be intentionally chosen to favor one or the other kind.

CHANGES THE FOOD UNDERGOES IN THE LARGE INTESTINE

Movements of the large intestine. — After the food passes from the small intestine into the large intestine, its regurgitation is prevented by the closure of the ileo-cæcal valve. When the cæcum becomes filled, strong contractions of the walls exert pressure upon the contained food and force it into the ascending colon. The waves of contraction which pass over the walls of the ascending colon are described as antiperistaltic because they pass in two directions, (1) from the small intestine, and (2) toward the small intestine. This delays the food, keeps it moving backward and forward, and helps absorption. It has been estimated that it

requires about two hours for the food to pass from the ileo-cæcal valve to the hepatic flexure, and about four and one-half hours to reach the splenic flexure.

Secretion of the large intestine. — The secretion of the large intestine contains much mucin, shows an alkaline reaction, and is not characterized by the presence of enzymes. When the contents of the small intestine pass the ileo-cæcal valve, they still contain a certain amount of unabsorbed food material. This remains a long time in the intestine, and since it contains the digestive enzymes received in the duodenum, the process of digestion and absorption continues.

By the abstraction of all the soluble constituents, and especially by the withdrawal of water, the liquid contents become, as they approach the rectum, changed into a firm and solid mass of waste matters, ready for ejection from the body, and called *feces*.

Action of bacteria in large intestine. — Protein putrefaction due to the action of bacteria is a constant and normal occurrence in the large intestine. The reaction is alkaline, and whatever protein may have escaped digestion and absorption is acted upon by the bacteria and undergoes putrefactive fermentation. The splitting of the protein molecule by this process is very complete, and the end-products differ from those resulting from the hydrolysis caused by acids or enzymes. The list of end-products of putrefaction is a long one. Some are given off in the feces, others are absorbed and later excreted in the urine. The action of bacteria is considered of doubtful value. It is possible that they may act upon the cellulose of vegetable foods and render it useful in nutrition. A conservative view is that bacteria confer no positive benefit, but under normal conditions the body is able to neutralize their injurious action.

The feces. — The feces consist of: (1) the undigested and indigestible parts of the food, (2) the products of bacterial decomposition, (3) great quantities of bacteria of different kinds, (4) bile and other secretions, (5) enzymes, and (6) inorganic salts. Some authorities teach that a certain amount of indigestible material in the diet is wholesome. It stimulates the lining of the intestines, promotes peristalsis, and as it is pushed along the tube takes with it the less bulky but more toxic wastes. The color of feces is due to the presence of pigments derived from the bile.

Defecation. — The anal canal is guarded by an internal sphincter muscle of the involuntary type, and an external sphincter that is voluntary, but both are supplied with nerves from the central nervous system and consequently defecation is a voluntary act. Normally the rectum is empty until just before defecation. Various stimuli (depending on one's habits) will produce peristaltic action of the colon, so that a small quantity of feces enters the rectum. This irritates the sensory nerve-endings and causes a desire to defecate. The voluntary contraction of the abdominal muscles, the descent of the diaphragm, and powerful peristalsis of the colon all combine to empty the colon and rectum.

One of the commonest causes of constipation is the retention of feces in the rectum because of failure to act on the desire for defecation. After feces once enter the rectum there is no retroperistalsis to carry it back to the colon, and the sense of irritation becomes blunted. The desire may not recur for twenty-four hours, and during this time the feces continue to lose water, become harder, and more difficult to expel.

ABSORPTION

This is the process by means of which the digested food is taken from the intestines and carried into the blood. We have now to consider this process, for, properly speaking, though the food may be digested and ready for nutritive purposes, it is practically outside the body, until it passes through the walls of the alimentary canal.

Absorption. — Absorption is a very complex process and may be subdivided into a physical and a physiological process. The **physical** process consists in the passage of the digested food from the intestines into the blood-vessels, and is governed by the laws of diffusion and osmosis. The **physiological** process consists in the building up of the end-products of digestion into the substances found in the blood. This process of reconstruction is dependent on the living epithelial cells that make up the intestinal walls.

Paths of absorption. — There are two paths by means of which the products of digestion find their way into the blood: —

(1) By the capillaries in the walls of the intestines.

(2) By the lymphatics in the walls of the small intestine (the lacteals).

There is reason to believe that but little absorption occurs in the stomach. It is now thought that by far the greater part of absorption is a function of the small intestine. Normally, the valuable part of the digested food has been absorbed before the colon is reached, but it is true that the colon possesses some reserve power of absorption, which may be considered supplementary to the absorption occurring in the small intestine. An interesting feature is the marked absorption of water. In the small intestine the loss of water due to absorption is made good by osmosis or secretion of water *into* the intestine, since the contents at the ileocæcal valve are quite as fluid as at the pylorus. In the large intestine water is absorbed in large quantities and there is no compensating secretion to offset this loss, hence the contents as they approach the rectum become more firm and solid.

SUMMARY

Digestion
- Physical process of changing food to a solution or emulsion.
- Chemical process of splitting large and complex molecules into smaller and simpler ones.

Food
- Any substance taken into the body to
  1. Provide material for growth of tissues.
  2. Provide material for repair of tissue waste.
  3. To supply heat and other kinds of energy.

Classification
- Chemical analysis shows that elements found in body are found in food. Classification based on presence or absence of carbon.
- Nutrients or Food Principles
  - Inorganic
    - Water.
    - Mineral matter or salts.
  - Organic
    - Carbohydrates.
    - Fats.
    - Proteins.

Water
- H_2O. About 66 per cent of body weight.
- Found in all tissues.
- Supplies fluid.
- Acts as solvent.
- Aids in elimination of waste.

Mineral Matter
- Chloride, Phosphate, Sulphate, Carbonate — of sodium and potassium.
- Phosphate, Carbonate — of calcium and magnesium.
- **Functions**
  1. To maintain alkaline or neutral reaction of body fluids.
  2. To furnish material for acidity or alkalinity of digestive fluids.
  3. To maintain osmotic pressure.
  4. To enter into bones, teeth, and cartilage.
  5. To assist in the clotting of blood.
  6. To influence elasticity and irritability of nerves and muscles.

Carbohydrates
- Consist of C, H, and O, the two latter in the proportion to form water. Include sugars and starches.
- **Simple or monosaccharids**
  - Glucose or dextrose $C_6H_{12}O_6$
  - Fructose or levulose $C_6H_{12}O_6$
  - (together:) Invert sugar.
- **Complex or disaccharids**
  - Sucrose or cane sugar $C_{12}H_{22}O_{11}$.
  - Lactose or milk sugar $C_{12}H_{22}O_{11}$.
  - Maltose or malt sugar $C_{12}H_{22}O_{11}$.
- **Polysaccharids**
  - Starch $(C_6H_{10}O_5)n$.
  - Cellulose $(C_6H_{10}O_5)n$.
  - Glycogen $(C_6H_{10}O_5)n$.
  - Dextrin $(C_6H_{10}O_5)n$.

Fats

- Consist of C, H, and O, but the H content is relatively high.
- Made from one molecule of glycerine and three molecules of fatty acid. Reaction comparable to neutralization of an acid by a base.

  Stearic acid + Glycerine → Stearin + Water

  $3\ H.\ C_{18}H_{35}O_2 + C_3H_5(OH)_3 \rightarrow C_3H_5(C_{18}H_{35}O_2)_3 + 3\ H_2O$
- Fats are liquid at body temperature.
- Soluble in ether, chloroform, and hot alcohol.
- Under influence of body enzymes split into substances out of which they are built. Reaction reverse of above.

  Stearin + Water → Glycerine + Stearic acid

  $C_3H_5(C_{18}H_{35}O_2)_3 + 3\ H_2O \rightarrow C_3H_5(OH)_3 + 3\ H.\ C_{18}H_{35}O_2$

Proteins

- Consist of C, H, N, O; S, P, and other elements may be present.
- Differ from carbohydrates and fats in having nitrogen, hence called nitrogenous.
- Built up of simpler substances called amino-acids.
- About twenty amino-acids have been described, and various combinations result in many different kinds of proteins.
- Digestion of proteins means hydrolysis of complex molecules into simpler ones, *i.e.*, protein → metaprotein → proteoses → peptones → peptids → amino-acids.
- **Classification**
  - Simple
    - Albumins
    - Globulins
    - Glutelins
    - Alcohol-soluble proteins
    - Albuminoids
    - Histons
    - Protamins

    } Yield amino-acids on hydrolysis.
  - Conjugated
    - Nucleoproteins — yield amino-acids and nuclein.
    - Glycoproteins — yield amino-acids and a carbohydrate.
    - Phosphoproteins — yield amino-acids and a phospho body.
    - Hæmoglobins — yield amino-acids and hæmatin.
    - Lecithoproteins — yield amino-acids and a fatty substance.

- **Proteins**
  - **Classification**
    - Derived
      - Primary derivatives (formed through hydrolytic changes which cause only slight alterations of the protein molecule)
        - Proteans.
        - Metaproteins.
        - Coagulated proteins.
      - Secondary derivatives (products of further hydrolytic cleavage of the protein molecule)
        - Proteoses.
        - Peptones.
        - Peptids.

- **Accessory Articles of Diet.**
  - Flavors: The various oils and esters that give odor and taste to food.
  - Condiments: Salt, pepper, mustard, etc.
  - Stimulants: Tea, coffee, cocoa, meat extracts.

- **Digestive Processes**
  - **Mechanical**
    - Mastication.
    - Deglutition or swallowing.
    - Peristaltic action of œsophagus.
    - Movements of stomach.
    - Movements of intestines.
    - Defecation.
  - **Chemical**
    - Splitting of complex substances into simpler ones.
    - Process of hydrolysis that is dependent on enzymes.
    - Rendered necessary by variety and complexity of foods, which must be reduced to standard and simple substances that the tissues can use,
      - *i.e.*,
        - Simple sugars.
        - Glycerine and fatty acids.
        - Amino-acids.

- **Enzymes**
  - Substances produced by living cells which act by catalysis.
  - Efficacy destroyed by boiling.
  - Act best at body temperature.
  - Require medium of definite reaction.
  - Antecedent or inactive form called *zymogen*.
  - Substances which help or act with an enzyme called *co-enzymes*.

Enzymes — Classification:

1. Sugar-splitting
   - *a.* Inverting.
   - *b.* Enzymes which act on simple sugars.
2. Amylolytic or starch-splitting.
3. Lipolytic or fat-splitting.
4. Proteolytic or protein-splitting.
5. Clotting enzymes.
6. Oxidizing enzymes, or oxidases.
7. Deaminizing enzymes.

LIST OF DIGESTIVE FLUIDS AND CHIEF ENZYMES

DIGESTIVE FLUIDS	ENZYMES		FUNCTIONS
Saliva	Ptyalin or salivary diastase		Hydrolyzes starch to dextrin and sugar (maltose).
Gastric Fluid	Pepsin		In an acid medium hydrolyzes proteins into proteoses and peptones.
	Rennin		Curdles the caseinogen of milk.
Pancreatic Fluid	Trypsin		In a slightly acid, neutral, or strongly alkaline medium, splits proteoses into peptones and amino-acids.
	Diastase or Amylase		Hydrolyzes starch to dextrin and sugar (maltose).
	Lipase (Steapsin)		Splits fats to glycerine and fatty acids.
Succus Entericus	Enterokinase		Activates the trypsinogen, and converts it into trypsin.
	Erepsin		Hydrolyzes proteoses and peptones to amino-acids.
	Inverting	Maltase	Hydrolyzes dextrin and maltose to dextrose.
		Invertase	Hydrolyzes sucrose to dextrose and levulose.
		Lactase	Hydrolyzes lactose to dextrose and galactose.
Bile	No enzyme		Serves as coenzyme and activates the lipase of the pancreatic fluid.

Changes Food undergoes in Mouth
- Mastication (chewing).
- Insalivation (mixing with saliva).
- **Saliva**
  - Secreted by salivary glands: Parotid, Submaxillary, Sublingual — and mucous glands of mouth.
  - Result of
    1. Reflex stimulation.
    2. Psychical.
  - Consists of water, mucin, and enzyme — **ptyalin.**
  - Specific gravity 1.004–1.008. Alkaline reaction.
  - One or two quarts in 24 hours.
  - **Functions**
    1. Assists in mastication and deglutition.
    2. Serves as a lubricant.
    3. Dissolves or liquefies the food, thus stimulating the taste nerves, and indirectly the secretion of gastric fluid.
    4. Hydrolyzes starch to dextrin and maltose.
- Deglutition (swallowing).

Stomach Digestion
- Movements of stomach.
- Serves as reservoir.
- Maintains a gradual delivery to intestine.
- Time required for stomach digestion about 5 hours.
- Secretion of gastric fluid
  - Psychical.
  - Chemical — Secretin.
- **Gastric fluid**
  - Secreted by glands of stomach
    - Cardiac.
    - True gastric or peptic.
    - Pyloric.
  - Acid reaction due to free hydrochloric acid, about 0.2 to 0.4 per cent.
  - Enzymes
    - Pepsin.
    - Rennin.
    - Gastric lipase.

- **INTESTINAL DIGESTION**
  - **Small Intestine**
    - Movements of small intestine
      - Peristaltic.
      - Pendular or rhythmic segmentation.
    - **Pancreatic fluid**
      - Secretion of pancreatic fluid
        - Psychical.
        - Chemical — secretin.
      - Secreted by pancreas, discharged into small intestine during digestion.
      - Viscid fluid, alkaline reaction.
      - **Enzymes**
        - Trypsin.
        - Diastase.
        - Lipase.
    - **Succus entericus**
      - Secreted by glands found in intestines
        - 1. Intestinal or Lieberkuhn's.
        - 2. Duodenal or Brunner's.
      - Yellowish fluid, alkaline reaction, contains mucin.
      - **Enzymes**
        - Erepsin.
        - Inverting.
      - **Hormone** — Secretin.
    - **Bile**
      - Golden brown or greenish liquid with alkaline reaction.
      - Secreted by liver, stored in gall-bladder, discharged into small intestine during digestion.
      - **Action**
        - 1. Coenzyme — activates lipase of pancreatic fluid.
        - 2. Digestive secretion — aids lipase in hydrolysis of fats and aids in absorption of split products.
        - 3. Thought to excrete products of disintegration of hæmoglobin.
        - 4. Questioned antiseptic action on intestinal contents.
    - **Bacteria**
      - Decompose carbohydrates.
      - Little or no effect on protein.
  - **Large Intestine**
    - Movements of large intestine
      - Peristaltic.
      - Antiperistaltic.
    - Time required for food to pass from cæcum to splenic flexure about $6\frac{1}{2}$ hours.
    - **Secretion**
      - Alkaline reaction.
      - Contains a great deal of mucin.
      - No enzymes.
    - **Bacteria**
      - Hydrolysis of proteins constant.
      - Possible action on cellulose.
      - Benefit doubtful.
    - **Feces**
      - Undigested and indigestible portions of food.
      - Products of bacterial decomposition.
      - Great quantities of bacteria.
      - Bile and other secretions.
      - Enzymes and inorganic salts.
    - **Defecation** — This term is applied to the act of expelling the feces from the rectum.

Absorption

- Process of taking up digested foodstuffs and carrying them to the blood.
- **Two processes**
  - **Physical** — Diffusion and osmosis.
  - **Physiological** — Reconstruction of end-products of digestion into substances found in the blood.
- **Paths of absorption**
  1. Capillaries in the walls of the intestines. This blood is carried by means of portal vein to liver, from liver by hepatic veins to inferior vena cava, thence to right auricle.
  2. Lymphatics in the walls of small intestine (lacteals) absorb digested fats and empty into chyle cistern of thoracic duct, superior vena cava, and right auricle of heart.

CHAPTER XVI

GENERAL METABOLISM; METABOLISM OF CARBOHYDRATES; METABOLISM OF FATS; METABOLISM OF PROTEINS. — DUCTLESS GLANDS

The nutritive processes in the human body include: (1) the reception and digestion of food, followed by absorption of the different food products, and the distribution of these products to all the cells by the circulating liquids of the body; (2) the absorption of oxygen by the circulating liquids in the lungs, its distribution to all the cells of the body, and its union with the constituents of the cells. We have studied digestion and absorption, and our special problem in this chapter is metabolism.

METABOLISM

General metabolism includes all the changes that occur in digested foodstuffs from the time of their absorption until their elimination in the excretions. Sometimes the term is used more specifically to relate to the chemical activities that take place within cells.

Functions of metabolism. — Metabolic changes serve two important purposes: (1) the repair and growth of tissue, and (2) the release of chemical energy in the form of heat, nervous activity, and muscular activity.

Factors which promote metabolic changes. — The factors which promote metabolic changes are: (1) enzymes, (2) oxygen, and (3) internal secretions. It was formerly taught that the oxygen absorbed from the lungs was responsible for all the processes of oxidation that occur in the body. More accurate study has demonstrated that while oxygen is an important factor, it is only one, and the enzymes that are present in nearly all the body tissues are capable of splitting complex materials into simpler substances. Moreover, it is generally considered that the action of the tissue

enzymes comes first and causes splitting by hydrolysis, then other enzymes termed **oxidases** activate the process of oxidation.

Metabolic changes. — These chemical changes can be classified under two heads: (1) **anabolism**, or the building-up processes, and (2) **katabolism**, or the splitting of complex substances into simpler ones. The most important are as follows: —

A. The cells take from the blood the substances which they require for repair and growth, and build it up into protoplasm. This involves the conversion of non-living material into the living protoplasm of the cells, and is an example of anabolism.

B. Oxidation, or the union of oxygen with the constituents of the cells, resulting in the release of energy and the breaking down of complex substances into simpler products. This is an example of katabolism.

Some of the simpler products that result from oxidation are acids. These acids must be eliminated or changed chemically, as all the digestive fluids of the body, with the exception of the gastric fluid, are alkaline or neutral, and this condition is essential to nutrition and even to the immediate continuance of life. (*a*) Some of the weaker acids are eliminated in the urine; one, carbonic acid (H_2CO_3), is a very unstable compound and breaks down to form water (H_2O) and carbon dioxide (CO_2). (*b*) When proteins are oxidized, sulphur is set free. This sulphur (S) unites with water (H_2O) and oxygen (O_2) to form sulphuric acid (H_2SO_4). Sulphuric acid is promptly neutralized by the alkalies present in the tissues, so that the body never contains sulphuric acid but does contain sulphates and water, which result from the process of neutralization. (See page 8.)

C. The conversion of glucose into glycogen, and the reconversion of glycogen into glucose.

D. The conversion of glucose into fat.

E. The conversion of fat into glucose.

F. The conversion of amino-acids to glucose.

G. The conversion of amino-acids to fat.

METABOLISM OF CARBOHYDRATES

It is convenient to consider the history of carbohydrates under three heads: (1) its supply; (2) its storage; and (3) its consumption.

(1) The supply is regulated by the diet.

(2) The storage is provided for temporarily by the liver, the muscles, and the cells of all tissues.

During the process of digestion all the carbohydrates are changed to simple sugars. It is possible that a small amount of sugar is absorbed in the stomach, but by far the greater part passes into the capillaries of the small intestine. These capillaries pour their contents into the portal vein, which carries the blood rich with glucose to the liver. The liver cells take this glucose from the blood, and by putting together a number of molecules and withdrawing water,[1] the soluble glucose is changed to insoluble glycogen, which is stored in the liver cells. In thus storing up glycogen and doling it out as needed, the liver helps to maintain the normal quantity of glucose — 0.1 to 0.15 per cent — in the blood. From the blood stream glucose is taken up by the muscles and other cells and stored as glycogen until needed, or it may be oxidized at once. The maximum storage of glycogen in the body is about one pound. This means that the formation of glycogen cannot continue indefinitely, and if the carbohydrate intake is in excess of the current consumption, conditions are favorable for the development of fat from the surplus carbohydrates. This transformation is a well-established and frequent occurrence and is probably responsible for much of the obesity which is such a common condition.

(3) At the consumption end the amount of sugar oxidized is controlled by the energy needs of the tissues, particularly the muscles.

Factors controlling the metabolism of carbohydrates. — The metabolism of carbohydrates is under the control of the nervous system, but how this control is maintained is still an open question. One view is that there is a *sugar regulating centre* which may be influenced by the amount of sugar in the blood, just as the respiratory centre is influenced by the amount of carbon dioxide in the blood. If this is true, the way in which this centre exerts its control is complicated and indirect. There is much evidence to support the view that the internal secretion of the adrenal glands, of the pancreas, and of the hypophysis play a very important part.

[1] This is a process of dehydration and is exactly the opposite of hydrolysis. See page 8.

Functions of carbohydrates. — The oxidation of glucose serves the following purposes: (1) It furnishes the main if not the only source of energy for muscular work, and for all the nutritive processes of the body. (2) It furnishes an important part of the heat needed to maintain the body temperature. (3) It prevents oxidation of the body tissues, because it constitutes a reserve fund that is the first to be drawn upon in time of need. (4) An excess of carbohydrates over and above what can be stored as glycogen in the liver and muscles is converted into adipose tissue.

Waste products of carbohydrate metabolism. — The waste products resulting from the oxidation of glucose are carbon dioxide (CO_2) and water (H_2O). This process is thought to be comparable to the fermentation of sugar outside the body, and the same substances are formed, viz. alcohol, acids, carbon dioxide, and water.

Derangements of carbohydrate metabolism. — The storage of glycogen may be deranged by injuries to the central nervous system or by hypersecretion of the adrenal glands or the hypophysis, in which case hyperglycemia (excessive amount of sugar in blood) and glycosuria (sugar in the urine) result. Or the liver and muscles may be unable to store all the sugar absorbed from the alimentary canal, and in this case there is temporary hyperglycemia and glycosuria. Inability to oxidize the sugar at the consumption end brings on a hyperglycemia and glycosuria of a serious nature.

Diabetes mellitus. — Defective sugar metabolism is the central condition in this disease. When the body cannot oxidize sugar, the continual addition of digested sugar to the blood leads to hyperglycemia. When this state is reached, *i.e.*, the concentration of sugar in the blood exceeds the normal limit, the kidneys abstract it, and allow it to escape in the urine. In severe cases all the sugar entering the blood passes into the urine without having contributed to the activities of the tissues. The inability to oxidize sugar is accompanied by inability to make and hold glycogen in the liver and muscles. When diabetes reaches its full intensity, and no sugar can be broken down, there follows a faulty fat metabolism and acidosis of the gravest kind. (See page 338.)

METABOLISM OF FATS

The tendency of recent work is to favor the view that after fat is split into glycerine and fatty acids, it is absorbed by the epithelial cells of the villi and reconstructed in the very act of passing through them. This reconstruction is not a mere reproduction of the original fat. The glycerine and fatty acids combine in such proportion as to make the fat characteristic of the human animal. This fat passes into the lacteals of the villi. From these small lacteals it must find its way through the larger lymphatics in the mesentery to the thoracic duct, and then through the thoracic duct to the blood. This fat is carried by the blood to all the different parts of the body, and the tissues slowly take it out as they need it in their metabolic processes. Within the tissues it serves as fuel and is oxidized to supply the energy needs of the cells. If fat is burned outside the body, heat is liberated, and the waste products are carbon dioxide and water. This process is similar to the one that takes place in the body. Fat that is not required for the production of energy is stored up in certain parts of the body, but not all the adipose tissue found in the body is derived from fats, as excess carbohydrates are also stored as fat. In addition there is a possibility that fat may be formed from proteins. The amino-acids resulting from protein digestion, if in excess of what are needed to reconstruct body proteins, may be converted to sugar and glycogen, also to fat.

Functions of fat. — The uses of fat are (1) to serve as fuel and yield heat and other forms of energy. (2) To provide a store of reserve food to be drawn upon in time of need. When the supply of food is insufficient, or in diseased conditions, the body oxidizes first the glycogen stored in the muscles and liver, and then the fat stored in adipose tissue. (3) It acts as a protein sparer. In extreme conditions, when there is no glycogen or fat available, the body may oxidize the proteins of the tissues. If the supply of fat is large, it follows that the proteins of the tissues will be protected.

Derangements of fat metabolism. — When fat is fully oxidized the only end-products are carbon dioxide and water. In certain diseased conditions, for instance, severe diabetes, the oxidation of fat is incomplete, and certain compounds of an acid character are

formed. These may accumulate and be responsible for a condition of severe poisoning called *acidosis*.

The cause of obesity. — This condition is usually caused by eating more food than the body needs, especially fat and carbohydrates. The excess is stored as glycogen and adipose tissue. The needs of different individuals vary, depending on their mode of life, and on their capacity to oxidize food materials, so that a diet which will give an excess to one individual may in the body of another be entirely consumed. A sedentary life and absence of worry lessen the oxidation of food products and increase the tendency to take on flesh, while a very active muscular life has the opposite effect.

METABOLISM OF PROTEINS

As a result of digestion, proteins are hydrolyzed to amino-acids, and are absorbed by the blood capillaries of the villi. From the intestines this blood passes through the liver before it reaches the general circulation. Because of this it is considered possible that one stage in the metabolism of some of these amino-acids may be carried out in the liver. After a meal the amino-acids in the blood are increased in amount and are carried to all the tissues. The fate of these bodies varies. They may be taken up by the tissues, combined to form proteins, and used (1) during the period of growth to build up new tissue, and (2) both in youth, and after growth has ceased, to replace tissue that has been oxidized. Or they may split at once into a nitrogenous and non-nitrogenous part. The nitrogenous part passes to the liver, and is transformed into urea to be excreted by the kidneys. The non nitrogenous part is used in the formation of sugar and fat, and may be stored as glycogen and adipose tissue. Sooner or later it is oxidized, liberating energy.

Functions of proteins. — We have seen that the main function of proteins is to build up tissue, and they are the *one* class of foods capable of doing this. In addition they serve the same purpose as carbohydrates and fats and may even be converted into adipose tissue.

Nutritive value of different proteins. — Proteins vary in their constituents and in their nutritive value. Because of this they are classed as adequate and inadequate proteins. *Adequate* proteins contain all the constituents for the growth and maintenance of

the body. *Inadequate* proteins furnish material for energy needs, but not for growth and the repair of tissue waste. The difference between the two kinds seems to lie in the character of the amino-acids of which they are composed. Gelatine is an example of an inadequate protein. It is easily digested and absorbed, undergoes oxidation, which results in the liberation of energy and the production of urea, carbon dioxide, and water, but it does not supply the material needed for the repair of tissue waste. On the other hand, the casein of milk and the glutenin of wheat contain all the essential amino-acids and not only furnish energy, but can build tissue.

Nitrogen equilibrium. — The protein molecules are characterized by containing 16 per cent of nitrogen. After the metabolism of protein, nitrogen is eliminated chiefly in the urine, and to a limited extent in the feces. The body is said to be in nitrogen equilibrium when the amount of protein nitrogen taken into the body is equal to the amount eliminated in the excreta. If there is a plus balance in favor of the food, it means that protein is being stored in the body, and this is an ideal condition during the period of growth or convalescence from wasting illness. If the balance is minus, the body must be losing protein, but under normal conditions this does not occur. Nitrogen equilibrium may be maintained at various levels. That is, the amount of food eaten may be increased or decreased to a considerable degree without disturbing the equilibrium. This means that the greater the amount of nitrogen ingested, the greater the amount excreted. If nitrogen equilibrium can be estimated at various levels, the practical question which arises is: At what level should it be maintained to secure the best results? This question is difficult to answer. The average diets recommended range from 75–130 gms. protein per day, but experiments have shown that for considerable periods the body can be maintained on 35–40 gms. Our present knowledge does not warrant our stating that one is better or worse off for an excessively low protein diet.

Flavors and condiments. — The most important service rendered by these bodies is that by making the food appetizing they increase the secretion of gastric fluid.

Stimulants. — Under this heading is included tea, coffee, cocoa, and meat extracts. Tea and coffee owe their stimulating action

to caffeine. Cocoa, or the chocolate made from it, contains nourishment in the form of carbohydrate, fat, and protein. Its stimulating effects are due to theobromin, and are similar to those of caffeine. Meat extracts contain secretogogues which stimulate the gastric glands to secretion, but aside from this have little nutritive value.

Alcohol. — Alcohol is rapidly absorbed and quickly oxidized. It yields heat, and gives rise to carbon dioxide and water. It is not transformed into fat or glycogen, hence is not stored. Indirectly it may cause obesity in two ways: (1) moderate drinking creates a keen appetite and so favors overeating; (2) the oxidation of alcohol lessens the need for the oxidation of fats or carbohydrates. Thus fat is spared to be accumulated, or carbohydrates to be changed into it.

Energy value of food. — All the energy required for muscular work may be derived from the carbohydrates and fats provided they are supplied in sufficient quantities. If they are not, then protein is used as a source of energy. If there is an abundance of non-nitrogenous food, the amount of nitrogen excreted remains pretty constant. Exercise does not increase it, neither does sleep decrease it.

In health the temperature of the body is comparatively constant,[1] despite the changes in outside temperature. The supply of heat needed to maintain this constant temperature is derived from the oxidation of non-protein food. The amount of chemical energy in any substance determines its heat value. This may be ascertained by burning the substances and noting the amount of heat given off. It matters little whether the burning occurs in a test tube or in the living body. The heat produced is measured in terms of calories by means of a calorimeter. A large calorie (cal.) is the amount of heat required to raise one kilogram of water 1° C. The large calorie (Cal.) is the one referred to in physiology. As the result of many tests the caloric value of the different foodstuffs has been found to be as follows:[2] —

Carbohydrate	1 gm. = 4 cal.
Fat	1 gm. = 9 cal.
Protein	1 gm. = 4 cal.

[1] See page 389.

[2] These figures are lower than those usually given, *e.g.*, carbohydrate 4.1, fat 9.3, and protein 4.1, which are now known to allow too little for losses in digestion.

The amount of food necessary for normal nutrition. — In a normal condition the main object of food is: (1) to furnish the material for the growth and maintenance of tissue, and (2) to furnish energy for heat, muscular work, etc. The most important factors influencing the amount of food required are age, activity, and in lesser degree, size, shape, body composition, lactation, and climate. The greater the amount of muscular work, the greater the amount of food required. Children need more food in proportion to their weight than adults, because they are more active internally and externally, and in addition must provide for the growth of new tissue. Increased age usually means less active life as well as less active metabolism and thus less food is required. Women, as a rule, require less food than men, because they are smaller, have less active tissue in proportion to weight, and tend to more sedentary life. In an extremely cold climate more food is required for heat production in order to make up for the loss of heat from the body. It is ordinarily estimated that the daily diet should yield between 2300 and 2400 calories for an individual weighing 60 kilograms (130 lb.); that is, about 40 calories for each kilogram of body weight.

An excellent authority on this subject recommends that the daily diet be arranged about as follows: —

			Calories
Carbohydrate	275 gm. × 4 =		1100
Fat	100 gm. × 9 =		900
Protein	75 gm. × 4 =		300
		Total	2300

Within certain limits the fats and carbohydrates may be substituted for each other. For a healthy person leading a normal life appetite and experience seem safe guides by which to control the diet. They will at least prevent undernutrition, and the consequent lessening of the body's natural powers of resistance to disease. The opposite danger of overeating is a real one, because an excess of food puts unnecessary strain upon the organs of nutrition and excretion, and favors the formation of excessive adipose tissue. Excess of proteins may overload the system with the products of intestinal putrefaction. Excess of carbohydrates may cause flatulence, due to fermentation of these foods. An excess of fat interferes with digestion by retarding the secretion of gastric fluid.

Vitamines. — Many nutrition experiments have made it evident that for growth and maintenance the human animal requires not only certain amounts of proteins, carbohydrates, and fats, but certain other essential substances called vitamines. (It has been suggested that *food hormones* would be a better name.) They do not serve as a source of energy and probably not as direct building stones, but they are in some (as yet undetermined) way essential to metabolism. Various animals have been fed on special diets amply covering all the needs in the way of protein, carbohydrate, and fat, but not foods containing vitamines. Young animals grow for a certain time, then come to a standstill, sicken, and die unless food containing vitamines is added to the diet. Other experiments have led some observers to suggest that certain diseases such as beriberi, scurvy, and pellagra are caused by a deficiency of vitamines in the diet. Vitamines are present in certain foods and absent in others. They are found in fresh fruit juices, milk, eggs, and in the bran of wheat, rice, and other cereals.

DUCTLESS GLANDS

The ductless glands form a group of organs that produce secretions, called internal secretions, which leave the gland by the blood or lymph, and not by means of a duct. Many of the glands that possess ducts and form an external secretion form an internal secretion as well, *i.e.*, the liver and pancreas, but these are not classed as ductless, because the external secretion is carried out of the gland by means of a duct, though the internal secretion passes into the blood or lymph just as in the ductless glands. The function of the ductless glands is intimately connected with the purpose of the internal secretions, and this is imperfectly understood.[1] However, a diseased condition or removal of these glands produces symptoms which make evident their importance in the normal carrying out of the body functions.

The most important ductless glands are: —

(1) The Thyroid.
(2) The Parathyroids.
(3) The Thymus.
(4) The Adrenals (supra-renal capsules).
(5) The Hypophysis.
(6) The Epiphysis (Pineal body).
(7) The Testes (see page 477).
(8) The Ovaries (see page 463).

[1] See page 149.

(1) **The thyroid.** — The thyroid is a small, flat gland lying against the fore part of the trachea, below the thyroid cartilage. It is of a deep red color, weighs about an ounce (30 gms.), and consists of two lateral lobes connected at their lower parts by an isthmus. The lobes are broader below and taper to a point above. Small masses of thyroid tissue are sometimes found along the

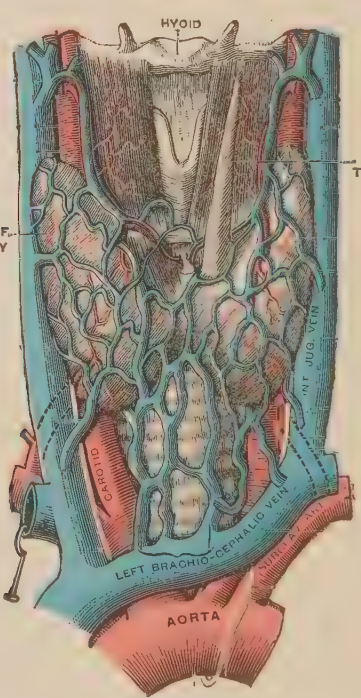


FIG. 179. — THE THYROID BODY AND THE RELATED BLOOD-VESSELS. (Gerrish.)

trachea as far down as the heart. They are called **accessory thyroids**. Comparatively little is known about the action of the thyroid secretion, but much clinical evidence supports the theory that it is necessary for the continuance of normal metabolism.

Cretinism is a condition caused by congenital defects of the thyroid or atrophy occurring in early life. The growth of the skeleton ceases and there is complete arrest of mental development. Children so afflicted are not only dwarfed, but ill-proportioned, having heavy heads and abdomens and weak muscles.

Myxœdema is a disturbed condition of metabolism that follows the removal or atrophy of the gland. The individual so

afflicted presents a peculiar appearance, as the subcutaneous connective tissue becomes thickened, the face and hands swollen and puffy. The mental faculties become blunted and idiocy results unless proper treatment is instituted.

Cretinism and myxœdema are both supposed to be due to a lack of the internal secretion of the thyroid, and much success has followed the administration of thyroid extract in various ways.

Goitre is a condition in which the gland is enlarged, but the secretion may not be interfered with.

Exophthalmic goitre is a disease characterized by extreme nervousness, quickened heart action, protruding eyeballs, and goitre. It is caused by an overabundant production of thyroid secretion, due to enlargement and overactivity of the gland.

(2) **The parathyroids.** — Embedded in the surface of each lateral lobe of the thyroid are two little masses, each about one-fourth inch (6.25 mm.) in diameter. They are solid accumulations of epithelioid cells, invested with a tunic of areolar tissue and well supplied with blood-vessels. The function of the parathyroids is supposed to consist in neutralizing toxic substances formed elsewhere in the body. In their absence acute tetanic convulsions develop.

(3) **The thymus.** — The thymus is a temporary organ attaining its full size at the end of the second year. Then it ceases to grow and remains practically stationary until puberty, at which time it degenerates. At the period of most active growth it consists of two lateral lobes situated below the thyroid and in front of the trachea.

The function of this gland is not known, but it is thought to have a definite connection with growth and with the development of the reproductive organs.

(4) **The adrenals or supra-renal capsules.** — The adrenals are small flattened bodies of a yellowish color which are placed one above each kidney. They secrete a substance called adrenalin, which owes its power to adrenin or epinephrin. This secretion raises the blood-pressure, slows the heart, and increases the amount of sugar in the blood. The rise in blood-pressure is due to the contraction of the blood-vessels, especially those of the abdominal viscera. These glands are supplied with secretory nerves which may be stimulated reflexly. Sensory stimuli and strong emotions

increase the activity of the gland. On the strength of these facts it has been suggested that the adrenals are *emergency organs;* that at times of great emotional stress, fear, anger, etc., their secretion is increased, resulting in an increased blood-supply for the muscles, as well as a rapid transformation of glycogen into

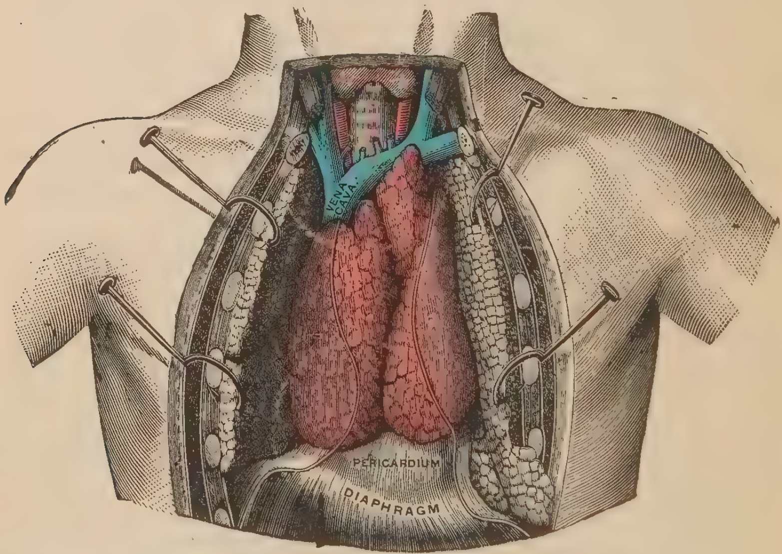


FIG. 180. — THE THYMUS, THE STERNAL AND COSTAL CARTILAGES HAVING BEEN REMOVED. (Gerrish.)

sugar, which at once enters the blood, and is readily available for the production of energy.

Another service of adrenin is to postpone fatigue. A very small addition of adrenin to the blood of an animal whose strength is flagging may give a renewed command of the muscles. It is now believed that "the strength of desperation" is due to the timely discharge of adrenin into the blood.

Under conditions of rest the adrenals exercise considerable influence, for if they are removed or wasted by disease, several indispensable hormones seem to be lost. In such cases the victim grows weak, suffers from incessant nausea, and dies as though from exhaustion.

(5) **The hypophysis.** — The hypophysis, also called the pituitary body, is of an ovoid form, a reddish gray color, and consists of two lobes. The anterior lobe is larger and distinctly glandular,

the posterior lobe is smaller and composed of nerve-cells and fibres.

The pituitary is lodged in a depression of the middle portion of the sphenoid bone, and is firmly held in place by the dura mater.[1]

From the results of various experiments it is evident that the pituitary body is essential to normal metabolism, and moreover that the anterior and posterior lobes exercise different functions. This differentiation in function cannot be made complete, but it would seem that the anterior lobe furnishes a secretion which stimulates the growth of the skeleton, possibly of all the connective tissues, and in addition exerts some essential influence on metabolism. The posterior lobe furnishes several hormones which have a stimulating effect on the tone of plain muscle, the secretory activity of several glands, and the process of glycogenolysis (changing glycogen to glucose). In addition it shares with the thymus and adrenals a regulating influence upon the normal development of the reproductive organs.

Gigantism, or excessive growth, and dwarfism, or underdevelopment, are thought to be due to abnormal conditions of this gland in early life. In later life abnormal conditions are attended with enlargement of the bones of the extremities and the features of the face, a condition known as *acromegaly.*

(6) **The epiphysis.** — The epiphysis or pineal body is a small reddish gray body located in the third ventricle of the brain. In early life it is glandular and attains its maximum growth about the seventh year. After this period, and particularly after puberty, it decreases in size, and the glandular tissue is replaced by fibrous tissue. It is thought that in early life the gland furnishes a secretion that inhibits growth, and restrains the development of the reproductive glands.

SPLEEN

Some authorities class the spleen with the ductless glands; other authorities question this, as it has not been possible to demonstrate that it furnishes an internal secretion. It is directly beneath the diaphragm, behind and to the left of the stomach, and is covered by the peritoneum. It is bean-shaped, convex on the

[1] See page 410.

outer surface, concave on the inner, and weighs usually from five to eight ounces (150 to 240 gms.). Beneath the serous coat it is covered by a fibrous and muscular capsule which sends fibrous bands (trabecules) to form a network in the interior of the organ. The meshes of this fibrous framework are filled with a substance called spleen pulp.

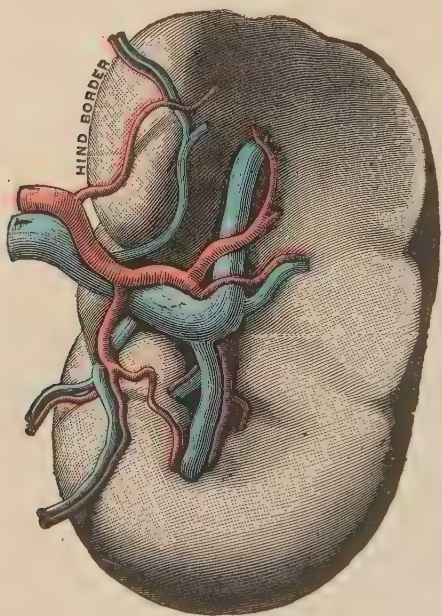


FIG. 181. — THE SPLEEN, SHOWING THE GASTRIC AND RENAL SURFACES AND THE BLOOD-VESSELS. (Gerrish.)

Blood supply. — Blood is supplied to the spleen by the splenic artery, which enters the concave side of the spleen at a depression called the hilus. The arrangement of the blood-vessels is peculiar to this organ. The splenic artery divides into several branches before entering the organ, and after entering rapidly divides into smaller vessels. When the minute arteriole stage is reached, the vessels terminate, and the blood escapes into the spleen pulp. The blood is collected from the pulp by thin-walled veins, which unite to form the splenic vein. The splenic vein unites with the superior mesenteric to form the portal vein, and carries the blood to the liver.

Functions. — The functions of the spleen are imperfectly understood, but it is usually credited with the following: —

(1) The formation of red cells during fœtal life and for a short period after birth.

(2) The presence of a large amount of iron suggests that it may help in the preparation of new hæmoglobin, or in the preservation of the iron set free by the death of the red cells. The presence of iron was formerly considered an evidence that the red cells were destroyed in the spleen, but this is not accepted at the present time.

(3) The spleen increases in size during digestion; after digestion is over it returns to its usual size. It is always large in well-fed, and small in starved animals. This supports the belief that it may be concerned in digestion or metabolism.

(4) It is probable that the spleen is concerned in the production of uric acid. Various waste products that result from the metabolism of proteins are found in the spleen, and it is thought that by the action of special enzymes these substances are changed to uric acid.

(5) In certain diseases, more especially typhoid and malaria, a temporary enlargement takes place. Some physiologists interpret this as an evidence that the spleen has an important protective function.

SUMMARY

Metabolism

- Refers to changes that occur in foodstuffs from time of absorption to elimination. Sometimes applied specifically to the chemical activities that take place within cells.
- **Functions**
  1. Repair and growth of tissue.
  2. Release of chemical energy in the form of heat, nervous, and muscular activity.
- **Dependent upon**
  - Enzymes.
  - Oxygen.
  - Internal secretions.
- **Equals the sum of the**
  - Anabolic or constructive changes.
  - Katabolic or destructive changes.
- **Consists of**
  - *A*. Conversion of non-living material into protoplasm.
  - *B*. Oxidation, including neutralization or elimination of acids.
  - *C*. Conversion of glucose into glycogen and the reconversion of glycogen into glucose.
  - *D*. Conversion of glucose into fat.
  - *E*. Conversion of fat into glucose.
  - *F*. Conversion of amino-acids to glucose.
  - *G*. Conversion of amino-acids to fat.

Metabolism of Carbohydrates

- **History**
  1. Supply regulated by diet.
  2. Storage provided for temporarily by liver, muscles, and cells of tissues. Simple sugars stored as glycogen.
  3. Consumption controlled by the energy needs of the tissues.
- **Dependent upon**
  - Control of nervous system, and the internal secretions of the adrenals, pancreas, and hypophysis.
- **Functions**
  - Furnish main source of energy for muscular work and all the nutritive processes.
  - Help to maintain the body temperature.
  - Form reserve fund for time of need (glycogen).
  - Protect the body tissues.
  - Excess carbohydrates are converted into adipose tissue.
- **Waste Products**
  - Carbon dioxide.
  - Water.
- **Derangements of**
  1. Interference with storage of glycogen.
  2. Inability to oxidize at consumption end.

Metabolism of Fats

- **Reconstruction** — In act of passing through epithelial cells of villi, glycerine and fatty acids combine to form fat peculiar to animal.
- **Functions**
  - Serve as fuel, yield heat and other forms of energy.
  - Form reserve fund for time of need (adipose tissue).
  - Act as protein sparers.
- **Waste Products**
  - Carbon dioxide.
  - Water.
- **Derangements of**
  - Results in formation of compounds of an acid character — acidosis.
- **Obesity**
  - Due to excessive amounts of carbohydrates and fats.
  - Sedentary life and absence of worry are contributing factors.

- **Metabolism of Proteins**
  - Absorbed as amino-acids, carried by blood to all the cells of the body.
  - **Functions**
    - 1. **Build up tissue.**
    - 2. Serve same purpose as carbohydrates and fats.
  - **Nutritive Value**
    - **Adequate** proteins contain all the materials for maintenance and growth of tissue.
    - **Inadequate** proteins serve same purpose as carbohydrates and fats.
  - **Nitrogen Equilibrium**
    - Condition when the amount of protein nitrogen taken into the body in food is equal to the amount eliminated in the excreta.

- **Accessory Articles of Food**
  - **Flavors and Condiments**
    - Have no nutritive value, but increase the secretion of gastric fluid.
  - **Stimulants**
    - Tea — stimulating action due to caffeine.
    - Coffee — stimulating action due to caffeine.
    - Cocoa
      - Contains carbohydrate, fat, and protein.
      - Stimulating effects due to theobromin
    - Meats Extract
      - Contain secretogogues which stimulate the gastric glands to secretion.
  - **Alcohol**
    - Oxidized rapidly, yields heat.
    - Waste Products
      - Carbon dioxide.
      - Water.
    - Favors Obesity
      - Moderate drinking creates keen appetite, and thus favors overeating.
      - Lessens need for oxidation of fat or carbohydrates, hence these are spared to accumulate.

- **Energy Value of Food**
  - **Oxidation** changes latent energy of food into energy of motion, and heat.
  - **Constant Temperature**
    - Supply of heat needed to maintain temperature, derived from oxidation.
  - **Calorie**
    - Unit of measurement for heat production.
    - Large calorie = quantity of heat necessary to raise one kilogram of water 1 degree centigrade.
  - **Carbohydrates** — 1 gm. = 4 cal.
  - **Fat** — 1 gm. = 9 cal.
  - **Protein** — 1 gm. = 4 cal.

Average Amount of Food Required

- **Dependent upon**
  - 1. Activity
  - 2. Age
  - 3. Size
  - 4. Sex
- About 40 calories for each kilogram of body weight.
- **Recommended Distribution**

		Cal.
Carbohydrate	275 gm. × 4 =	1100
Fat	100 gm. × 9 =	900
Protein	75 gm. × 4 =	300
	Total	2300

- **Undernutrition** — lessens natural powers of resistance to disease.
- **Overeating**
  1. Puts unnecessary strain on the organs of nutrition and excretion.
  2. Favors obesity.
  3. Increases amount of waste products, toxic material, and causes flatulence.
  4. Retards secretion of gastric juice.

Vitamines

- Substances essential to metabolism.
- Do not serve as source of energy or as direct building stones.
- Necessary for growth, and probably to prevent such diseases as beriberi, scurvy, and pellagra.
- Found in fresh fruit juices, milk, eggs, bran of wheat, rice, and other cereals.

Ductless Glands

- Glandular structures that possess no ducts.
- Produce internal secretions that are carried from the gland by the blood or lymph.
- Function is imperfectly understood.
- **Most important**
  - The Thyroid.
  - The Parathyroids.
  - The Thymus.
  - The Adrenals.
  - The Hypophysis.
  - The Epiphysis.
  - The Testes.
  - The Ovaries.

Thyroid

- Small gland. Weighs about one ounce.
- Consists of two lobes connected by an isthmus.
- Placed in front of trachea, below thyroid cartilage.
- Function not definitely known, but the internal secretion is thought to be necessary for the continuance of normal metabolism.

Parathyroids
- Four small masses, each about $\frac{1}{4}$ in. diameter.
- Two are embedded in each lobe of thyroid.
- Consist of epithelioid cells, invested with areolar tissue.
- Function is supposed to consist in neutralizing toxic substances.

Thymus
- Consists of two large masses of glandular tissue situated below the thyroid and in front of the trachea.
- Temporary organ. Attains its full size at end of second year. Then ceases to grow, remains stationary until puberty, at which time it degenerates.
- Function not definitely known, but it is thought to have a definite connection with growth and with the development of the reproductive organs.

Adrenals
- Small glands lying above each kidney. Weigh one drachm.
- Consist of a fibrous framework, the spaces of which are filled with groups of cells. They are enclosed in a fibrous capsule and are well supplied with blood-vessels, lymphatics, and nerves.
- Internal secretion — adrenalin, which owes its power to adrenin.
- **Functions**
  1. As emergency organs in times of emotional stress.
  2. To postpone fatigue.
  3. Furnishes seemingly indispensable hormones.

Hypophysis
- Small reddish gray gland.
- Consists of two lobes
  - Anterior lobe, large and glandular.
  - Posterior lobe, small and composed of nerve tissue.
- Lodged in depression of the sphenoid bone.
- **Functions**
  - Anterior lobe furnishes secretion which stimulates growth of skeleton, possibly all connective tissues, and exerts some essential influence on metabolism.
  - Posterior lobe furnishes several hormones which have a stimulating effect on tone of plain muscle, secretory activity of several glands, glycogenolysis, etc.

Epiphysis
- Small reddish gray body located in the third ventricle of the brain. Glandular organ; attains maximum growth about seventh year. From this period and particularly after puberty it decreases in size and becomes fibrous.
- Function not definitely known; it is thought to inhibit growth and restrain the development of the reproductive organs.

Spleen

- **Description**
  - Beneath diaphragm, behind and to the left of the stomach.
  - Consists of a fibrous network filled with a vascular pulp, enclosed in a fibrous and muscular capsule which is covered by serous membrane.
  - Blood supply peculiar — arteries — veins, no connecting capillaries.
- **Functions**
  - Not definitely known. Credited with the following: —
    1. Formation of red cells during fœtal life and for short period after birth.
    2. Helps in preparation of new hæmoglobin or preservation of iron set free by death of red cells.
    3. May assist in digestion and metabolism.
    4. May assist in production of uric acid.
    5. May protect body from infections.

CHAPTER XVII

WASTE PRODUCTS; EXCRETORY ORGANS; DESCRIPTION OF THE ORGANS CONSTITUTING THE URINARY SYSTEM; URINE

In the previous chapters we have seen that the blood is constantly supplied by means of the respiratory and digestive mechanisms with all the chemical substances it requires to maintain the life, growth, and activity of the body. These substances, entering the current of the blood, are carried to all the cells and are incessantly combining with the chemical substances of which these cells are composed. One of the results of these chemical combinations is the formation of waste products, which must be removed from the body, as many of them are toxic.

WASTE PRODUCTS

The wastes of cell metabolism may be listed as follows: —

1. Soluble Salts { Nitrogenous salts, *e.g.*, urea. Inorganic salts, *e.g.*, sodium chloride.
2. Liquid — Water.
3. Gas — Carbon dioxide.
4. Solids — Waste materials from food.

These wastes are classed as excreta and the process by which they are removed from the body as excretion or elimination.

EXCRETORY ORGANS

The organs that function as excretory organs and the products that they eliminate may be tabulated as follows: —

	Essential	Incidental
Lungs	Carbon dioxide	Water
Kidneys . . .	Water and soluble salts, resulting from metabolism of proteins, neutralization of acids, etc.	Carbon dioxide and solids.
Alimentary canal	Solids	Water, carbon dioxide, and salts.

In this chapter we devote ourselves to the consideration of the urinary system, which includes the following organs: —

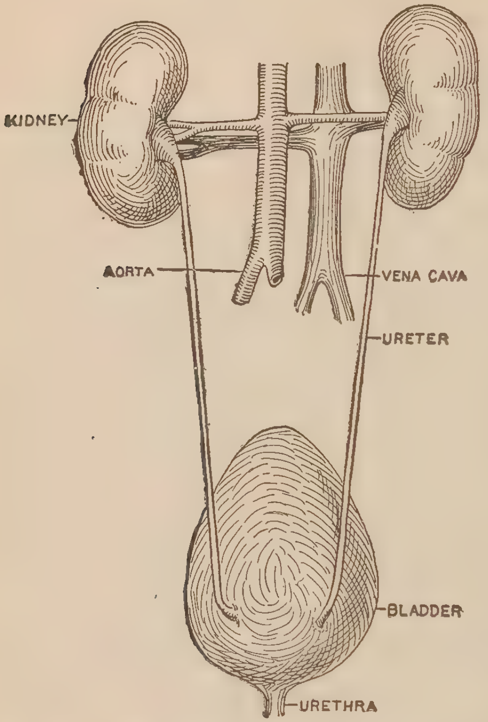


FIG. 182. — THE URINARY SYSTEM VIEWED FROM BEHIND.

Kidneys, which form the urine from materials taken from the blood.

Ureters, ducts which convey the urine away from the kidneys.

1 *Bladder*, a reservoir for the reception of urine.

Urethra, a tube through which the urine passes from the bladder and is finally voided.

KIDNEYS

The kidneys are two compound tubular glands, placed at the back of the abdominal cavity, one on each side of the spinal column and behind the peritoneal cavity. They correspond in position to the space included between the upper border of the twelfth thoracic and the third lumbar vertebra. The right is a little lower than the left in consequence of the large space occupied by the liver.

Capsule and supports. — The kidneys are covered by a thin but rather tough envelope of fibrous tissue called the capsule, the inner surface of which is slightly attached to the substance of the kidney by means of fine fibres and blood-vessels. The kidneys are usually embedded in a mass of fatty tissue termed the perirenal fat, and are not held in place by any distinct ligaments, but rather by the pressure and counter-pressure exerted upon them by neighboring structures.

Size and shape. — Each kidney is about four and one-half inches (11.2 cm.) long, two and one-half inches (6.2 cm.) broad, one and one-half inches (3.7 cm.) thick, and weighs about four and one-half ounces (135 gm.). They are bean shaped, with the concave side turned toward the spine, and the convex side directed outward. Near the centre of the concave side is a depression called the hilum, which serves as a passageway for the ureter,

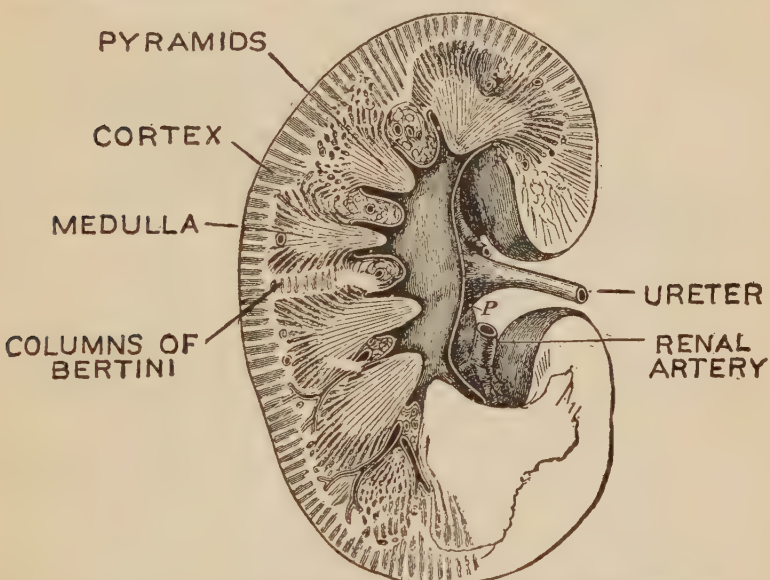


FIG. 183. — LONGITUDINAL SECTION OF THE HUMAN KIDNEY. (Modified from Huxley.)

and for the blood-vessels, lymph-vessels, and nerves going to and from the kidney.

Anatomy of the kidney. — If a kidney is cut in two lengthwise, it is seen that the upper end of the ureter expands into a basin-like cavity, called the *pelvis* of the kidney. This pelvis is irregularly subdivided into smaller, cup-like cavities, called *calyces*, which receive the pointed projections of the kidney substance.

The substance of the kidney is readily seen by the naked eye to consist of two distinct parts: (1) an outer, and more solid portion, called the cortex (bark); and (2) an inner, striated portion, called the medulla (marrow), which is not a solid mass, but more or less distinctly divided into pyramidal-shaped sections. The cortical substance penetrates for a variable distance between the

pyramids, separating and supporting them. These inter-pyramidal extensions are called the columns of Bertini and support the blood-vessels. The pointed projections, or *papillæ,* of the pyramids are received by the cup-like cavities or calyces of the pelvis. The bulk of the kidney substance, both in the cortex and medulla, is composed of little tubes or tubules, closely packed together, having

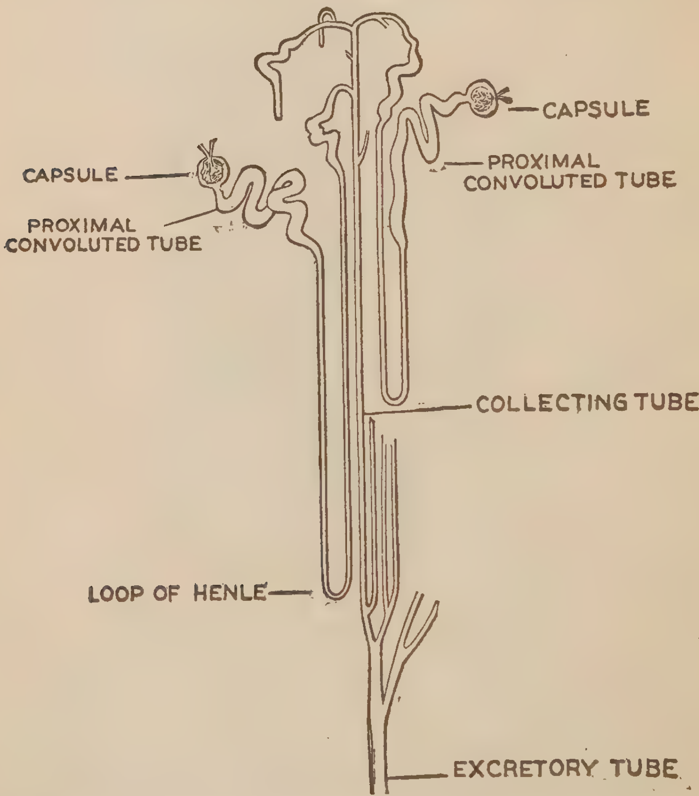


Fig. 184. — Diagram of the Course of Two Uriniferous Tubules.

only just enough connective tissue to carry a large supply of blood-vessels and a certain number of lymphatics and nerves.

Uriniferous tubules. — Examined under the microscope, it is seen that the uriniferous tubules begin as little hollow globes, called *capsules,* in the cortex of the kidney. These capsules are joined to the tubules by a constricted neck, and the tubules, after running a very irregular course, open into straight collecting tubes, which

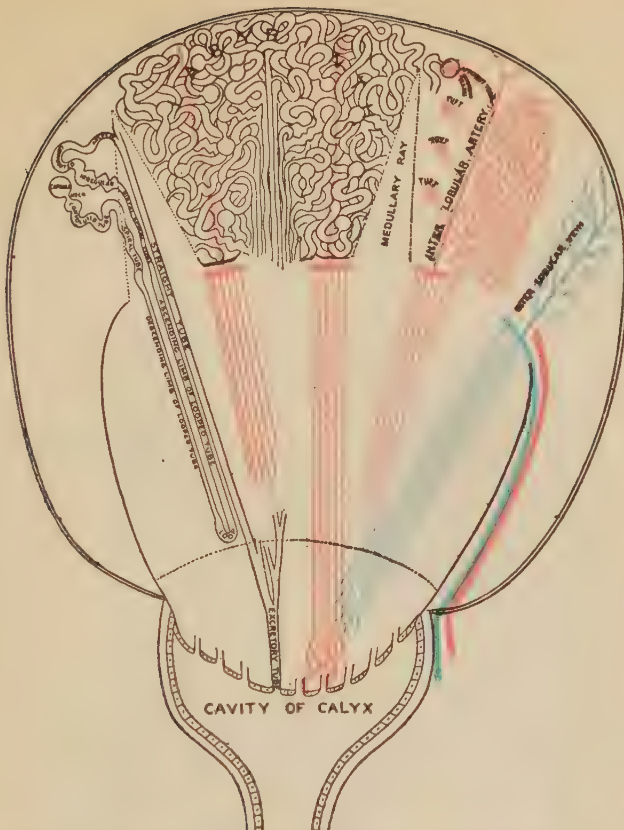


FIG. 185. — DIAGRAM OF THE STRUCTURE OF A LOBE OF THE KIDNEY. The lobe is seen in vertical section, the cortex being marked off from the medulla. Four medullary rays encroach upon the cortex. At the left is shown the course of a single continuous series of tubes — the straight and spiral tubes appearing in the medullary ray; the straight, looped, and excretory in the medulla proper; the capsule, neck, convoluted, irregular, and arched in the cortex proper. Next is seen the labyrinth, composed of a mass of tubes in the cortex, with a medullary ray for a centre. Equidistant from the ray on each side is a broken red line, marking the position of an interlobular artery. The parts between these lines constitute a lobule. Farther to the right is an interlobular artery, giving off lateral branches (afferent vessels), each of which ends in a tuft of capillaries, from which the blood is collected by an efferent vessel. The uppermost of the tufts is shown enclosed in a capsule. On the right of the interlobular artery the efferent vessels break up into a capillary network which surrounds the (unrepresented) tubes in the cortex and ray. The lowest efferent sends vertical vessels also into the medulla. On the right the interlobular vein is seen gathering the blood from all the parts supplied by the interlobular artery. A branch of the renal artery courses upward between cortex and medulla, and forms an arch (here broken) over the base of the medulla. From it the interlobular arteries pass upward into the cortex, and straight branches go downward into the medulla, supplying its structure, and ending at the apex in the capillaries. From the last the radicles of the renal vein arise, and accompany the straight arteries to the base of the medulla, where a venous arch is formed, continuous with which is the vena comes of the entering artery. The calyx embraces the apex of the medullary pyramid. It is lined with epithelium, which continues from it over the apex, the latter being perforated with the many apertures of excretory tubes. (Gerrish.)

pour their contents through their openings in the pointed ends or papillæ of the pyramids, into the calyces of the kidney.

The tubules are composed of basement membrane, lined throughout by epithelial cells. The cells vary in the different parts of a tubule, those of the capsule and convoluted or irregular parts being more especially adapted to secretory purposes than the straight parts of the tubule.

FIG. 186. — PLAN OF THE BLOOD-VESSELS CONNECTED WITH THE TUBULES.

Pyramid. — These collecting tubules *en masse*, together with interstitial tissue, blood-vessels, and lymphatics, make a pyramid. The number of pyramids varies.

Renal or Malpighian corpuscles. — In the cortical portion of the kidney are found renal corpuscles which consist of two parts: (1) a minute tuft of capillaries called a *glomerulus*, surrounded by (2) a closed *capsule* which is the beginning of a uriniferous tubule. The investment of the glomerulus by the capsule is double and

complete except at one point, where an afferent vessel enters and an efferent vessel leaves.

The blood supply of the kidney. — For its size, the kidney is abundantly supplied with blood. The renal artery, coming directly from the aorta, divides, before it enters the hilus of the kidney, into several branches, which pass into the tissue of the organ. Branches from these arteries have two destinations: (1) into the cortex, and (2) into the pyramids.

(1) When the arteries reach the level of the base of the pyramid, the branches divide laterally to form more or less complete arches between the cortex and medulla. From the arterial arches, vessels pass upward through the cortex (interlobular), giving off at intervals tiny arteries, each of which enters [1] the dilated commencement or capsule of a uriniferous tubule. These tiny arteries, entering the capsule, are spoken of as afferent vessels. They push the thin walls of the capsule before them, break up into a knot of capillary vessels, called a *glomerulus*, and finally issue from the capsule as efferent vessels, near the point at which the afferent vessel entered. These efferent vessels are much smaller than the afferent vessels. They do not immediately join to form veins, but break up into a close meshwork or plexus of capillaries around the tubules, before they unite to form the larger vessels and pour their contents into the veins. These veins terminate in venous arches between the cortex and medulla. It is in this way that the cortex is supplied with blood.

(2) The pyramids also receive their blood supply from the arterial arches. The blood passes downward in straight vessels between the uriniferous tubules, to be returned by more or less straight veins to the venous arches, whence it is conveyed by large branches into the renal vein, which leaves the kidney at the hilus and pours its contents into the inferior vena cava.

It is worthy of note that, unlike the lungs and the liver, the kidney receives blood from just one artery, and this blood distributed in different sets of vessels serves the purposes of nourishment for the kidney substance, and the purposes of excretion. It is from the capillaries of the glomeruli and the plexus of capil-

[1] The artery does not penetrate the wall of the capsule, but the knot of capillary vessels is contained within the capsule, as the heart is contained within the pericardium.

laries around the convoluted portion of the tubules, that the passage of waste material from the blood into the tubule takes place. Other capillaries serve to hold the blood that is used for nourishment.

Nerves and lymphatics. — The kidneys are well supplied with nerves derived from both the sympathetic and central nervous systems. Many of these nerves are vasomotor nerves, and by regulating the contraction and dilatation of the blood-vessels, they influence the blood pressure in the kidneys. They are also well supplied with lymphatics.

Function of the kidneys. — The function of the kidneys is to separate waste matters (urine) from the blood, and thus help to maintain its normal composition. The waste matters are those resulting from metabolism, particularly of proteins; water, salts, and foreign matters such as toxins, whether formed in the body, or taken into the body from outside. The concentration of urine, and not the quantity, is our criterion for judging the amount of work done by the kidneys. It is probable that they are most severely taxed when they have to remove from the blood a maximum of dissolved solids in a minimum of water.

The secretion of urine. — The exact way in which the kidneys separate the urine from the blood is not known, but it is thought to be a double process, being partially accomplished by a mechanical filtration and partially by secretion due to the selective action of the cells lining the tubules.

(1) Into each hollow capsule which forms the beginning of a uriniferous tubule an afferent artery enters. This artery breaks up into capillaries which form a bunch of looped and twisted blood-vessels called a *glomerulus*. The walls of the capsule being double, the glomerulus pushes back the inner wall or visceral layer, until the capsule is entirely filled, leaving only a small space between it and the outer wall or parietal layer. The blood in the glomerulus is only separated from the interior of the tubule by the thin walls of the capillaries and the inverted wall of the capsule. The artery (afferent) which enters the capsule is larger than the issuing (efferent) vessel, and during its passage through the glomerulus, the blood is subjected to considerable pressure. As a result of this, a transudation of the watery constituents of the blood, with some dissolved salts, takes place through the

walls of the blood-vessels and the walls of the capsule into the capsular space, then into the tubule.

(2) After leaving the capsule, the efferent vessel communicates with other similar vessels, which together form a meshwork or plexus of capillaries closely surrounding the tubules, so that the blood is again brought into close communication with the interior of the tubules. The tubules are lined with secreting cells, and these cells appear to have the power of selecting from the blood the more solid waste matters (especially the urea), which fail to filter through the flat cells forming the wall of the capsule.

THE URETERS

The ureters are the excretory ducts of the kidneys. They consist of a distended portion called the *pelvis*, which is contained within the kidney, and a *duct*. Each duct is about the diameter of a goose-quill, and from ten to twelve inches (25 to 30 cm.) long. They consist of three coats: an outer fibrous coat, a middle muscular, and an inner mucous lining which is continuous above with that of the pelvis of the kidney, and below with that of the bladder.

Fig. 187. — Diagram Showing Method of Entrance of the Ureter into the Bladder. (Gerrish.)

Function. — The ureters connect the kidneys with the bladder and serve as a passageway to convey urine from the kidneys to the bladder.

BLADDER

The bladder is a hollow muscular organ situated in the pelvic cavity behind the pubes, in front of the rectum in the male, and in front of the anterior wall of the vagina, and the neck of the uterus, in the female. It is a freely movable organ, but is held in position by ligaments. During infancy it is conical in shape and projects above the upper border of the pubes into the hypogastric region. In the adult, when quite empty, it is placed deeply in the pelvis; when slightly distended, it has a round form; but when greatly distended, it is ovoid in shape and rises to a considerable height in the abdominal cavity. It is customary to speak of the widest

part as the *fundus*, and the part where the bladder becomes continuous with the urethra as the neck, or *cervix*. It has four coats: —

1. The **serous** coat is a reflection of the peritoneum, and only covers the upper portion of the fundus.

2. The **muscular** coat has three layers, an inner longitudinal, middle circular, and outer longitudinal. The circular fibres are collected into a layer of some thickness around the cervix or neck, where the bladder becomes continuous with the urethra. These circular fibres around the neck form a sphincter muscle which is normally in a state of contraction, only relaxing at intervals, when the accumulation of urine within the bladder renders its expulsion necessary.

3. The **areolar** coat connects the mucous and muscular.

4. The **mucous** membrane lining the bladder is continuous with that of the ureters and the urethra.

Function. — The bladder serves as a reservoir for the reception of urine. When moderately distended, it holds about one pint (about one-half litre).

THE URETHRA

The urethra is a narrow, membranous canal, about an inch and a half (3.8 cm.) in length in the female. Its normal diameter is about one-quarter of an inch (6.3 mm.), but it admits of considerable dilatation. It extends from the neck of the bladder to the external orifice, which is named the meatus urinarius. It is placed behind the symphysis pubis, and is embedded in the anterior wall of the vagina. Its direction is obliquely downward and forward, its course being slightly curved, with the concavity directed forward and upward. Its external orifice is the narrowest part and is located between the clitoris and the opening of the vagina. (See Fig. 222.)

The wall of the urethra consists of three coats, an outer muscular coat, a submucous coat, and an inner mucous coat which is continuous with that of the bladder.

MICTURITION

Urine is secreted continuously by the kidneys. It is carried to the bladder by the ureters, and at intervals is expelled from the

bladder through the urethra. The act by which the urine is expelled is called micturition. It occurs normally as the result of irritation due to the accumulation of urine within the bladder. The accumulation stimulates the muscular walls to contract, and the resistance of the sphincter at the neck of the bladder is overcome. The action is involuntary, but it may be controlled by voluntary effort.

Involuntary micturition. — Involuntary micturition may occur as the result of lack of consciousness, and as the result of spinal injury involving the nerve centres which send nerves of control to the bladder. It may be due to a want of *tone* in the muscular walls, or it may result from some abnormal irritation.

Retention of urine. — Retention or failure to void urine may be due to: (1) dulling of the senses so that there is no desire to void, (2) nervous contraction of the urethra, and (3) some obstruction in the urethra or in the neck of the bladder.

In some cases the bladder may become so fully distended that the retention of urine may be accompanied by more or less constant voiding of small amounts of urine.

Suppression of urine. — A far more serious condition than retention is the failure of the kidneys to secrete urine. This is spoken of as suppression, and is usually due to extreme congestion of the kidneys, as in acute nephritis.

THE URINE

Normal urine may be described as a transparent, amber-colored liquid, with a characteristic odor, an acid reaction when tested with litmus paper, and a specific gravity of about 1.020.

Transparency. — The transparency of urine may be diminished in health by the presence of mucus, derived from the genito-urinary tract, or by the deposit of salts. In disease the urine may become clouded by the presence of pus.

Color. — The color of urine depends upon the quantity voided and the relative amounts of water and coloring matters. If the quantity is abnormally increased, it is usually more dilute and of a paler color; as, for instance, the copious light-colored urine of hysteria or diabetes insipidus. One exception to this is diabetes mellitus, where the quantity is increased, but the color is dark

because of the presence of sugar. When the quantity is diminished as in fevers, it is generally highly colored, because the amount of solids present is large. Other causes of change of color are the presence of abnormal substances, and large doses of certain drugs.

Reaction. — The reaction of human urine is largely dependent on the kind of food eaten. Many of the waste products that result from a mixed diet are acid, hence the reaction of human urine is usually acid. On a diet of vegetables the urine will be alkaline, as it is with herbivorous animals. If human urine is allowed to stand for any length of time, it will become alkaline, because bacteria will decompose the protein constituents into ammonia and other alkalies. In certain diseased conditions of the urinary organs this same process takes place within the body.

Specific gravity. — The specific gravity depends upon the amount of solid waste matters present in the urine. In health, it may vary from 1.010 to 1.030. When the solids are dissolved in a large amount of water, the specific gravity will naturally be lower than when the urine is more concentrated. A high specific gravity denotes the presence of abnormal constituents; as, for instance, the specific gravity is notably heightened by the presence of sugar in diabetes mellitus.

Quantity. — The average quantity of urine secreted in twenty-four hours by a healthy adult is from forty to fifty ounces (1.2 to 1.5 litres). A child voids relatively more urine than an adult, but absolutely it voids less.

From 2–5 years, 16–24 ounces (480–720 cc.).
From 5–8 years, 24–32 ounces (720–960 cc.).
From 9–16 years, 32–40 ounces (960–1200 cc.).

The quantity of urine may be increased by (1) the ingestion of a large amount of liquid, (2) the action of diuretics, (3) nervousness, (4) certain diseases such as diabetes insipidus, diabetes mellitus, and hysteria.

The quantity of urine may be decreased by (1) the ingestion of a small amount of liquid, (2) vomiting, (3) diarrhœa, (4) high fever, (5) disease of the kidneys, and (6) the action of diaphoretics, muscular activity, or any treatment that induces free perspiration.

COMPOSITION OF URINE

The composition of urine is very complex; even in health it varies, depending on the quantity and kind of food eaten, etc. It is not difficult to understand this complexity when one recalls that the kidneys eliminate some of all the end-products resulting from food metabolism, together with the products of bacterial fermentation in the stomach and intestines. Under pathological conditions the composition may be still further modified. It is not possible to describe all the numerous constituents here. A few are as follows: —

- **Urine**
  - **Water,** 95 per cent
  - **Soluble salts** 5 per cent
    - Organic, about 3.7
      - **Urea** (2 per cent of total solids).
      - Purin bodies
        - Uric acid.
        - Xanthin.
        - Hypoxanthin.
      - Creatinin.
      - Hippuric acid.
      - Other substances.
    - Inorganic, about 1.3
      - Sodium chloride.
      - Sulphates.
      - Phosphates.
      - Salts of
        - Potassium.
        - Ammonium.
        - Magnesium.
        - Calcium.
      - Other substances.

Urea. — Urea constitutes about one-half of the solid constituents of the urine, and represents the chief end-product resulting from the metabolism of the proteins of the food and tissues. The result of the oxidation of protein material exists in the blood until it reaches the liver. Under the action of the liver cells this material is converted into urea. About 0.028 per cent of urea is present normally in the blood and tissues. The kidneys constantly remove urea as it is formed, and by their activity keep the amount of urea in the blood at the low level given above. If, for any reason, the kidneys fail to eliminate urea, the accumulation in the blood and tissues leads to a condition of poisoning.

Normally an adult voids about one ounce (30 gms.) of urea in

twenty-four hours, but the quantity is increased by a diet rich in proteins, strenuous exercise, hot baths, fever in its early stages, and some diseases. A small amount of protein food, excessive vomiting, free perspiration, and diseases that interfere with elimination will decrease the amount of urea voided.

Purin bodies. — In the classification of proteins given on page 309 nucleoproteins are listed. These are compounds of protein with a complex organic acid called nucleic acid, which contains phosphorus. They are found in the nuclei and protoplasm of body cells, also in various protein foods. When nucleoproteins either of the food or tissues are oxidized in the body, they give rise to purin bodies, *i.e.*, uric acid, xanthin, and hypoxanthin. Uric acid is the most important, and next to urea is the medium by which nitrogen is eliminated from the body. Uric acid combines with potassium and sodium to form urates, and is found in the form of urates in the urine. In gout the excretion of urates is decreased, and it accumulates in the blood and is deposited in the joints in the form of insoluble salts. In this and similar conditions purin-free diets, *i.e.*, diets free from nucleoproteins, are prescribed.

Creatinin. — Creatinin occurs in the urine constantly. Its physiological history is imperfectly known. Under normal conditions the amount of creatinin formed in the body is independent of the proteins eaten. This has led some observers to think that it represents an end-product of the metabolism of protein tissue.

Creatin [1] is found in the muscles, liver, heart, brain, and other organs. Nothing definite is known of the function of creatin, but it is probable that from it the creatinin of the urine is formed. Creatin is absent from normal urine, but is present in the urine during starvation, in acute fevers, and in conditions where there is a rapid loss of muscular tissue.

Hippuric acid. — Hippuric acid represents one of the chemical methods of defence of the organism against toxic substances. The amount found in the urine varies with the diet. On a diet containing much fruit and vegetables the amount excreted is increased. As a result of the digestion, fermentation

[1] The formula for creatin is $C_4H_9N_3O_2$.
The formula for creatinin is $C_4H_7N_3O$.
The difference is H_2O. Creatinin is the anhydride of creatin.

by bacteria, or oxidation of fruits and vegetables, certain toxic acids are formed, *e.g.*, benzoic acid. This is rendered less toxic by combining it with glycocoll to form hippuric acid which the kidneys excrete.

Salts. — The salts found in the blood are derived partly from the food eaten, and partly from the metabolism of proteins, particularly the neutralization of acids. Sodium chloride is the most abundant, and, next to urea, is the chief solid found in urine. In certain inflammatory conditions, coupled with serous exudate, *e.g.*, pneumonia, the amount of sodium chloride excreted is very much diminished.

Abnormal constituents. — The chief abnormal constituents that are liable to appear in the urine are albumin, glucose, indican, acetone, casts, calculi, pus, and blood.

Albumin. — Normally the kidney cells do not allow albumin to pass into the tubules, but a condition of temporary albuminuria may follow overeating or severe muscular exercise. In abnormal conditions of the kidneys associated with nephritis and acute fevers, albumin is usually found in the urine. In cases of heart disease, where the blood-vessels of the kidneys are subjected to abnormal pressure changes, albumin is usually present in the urine.

Glucose. — Normal urine contains no sugar, or so little that for clinical purposes it may be considered absent. In health the amount of glucose present in the blood varies from 0.1 to 0.15 per cent. A higher per cent is irritating to the tissues, so when the quantity of sugar eaten is greater than the system can promptly change to glycogen and fat, the kidneys secrete and excrete it. When glucose is found in the urine from this cause, it is called *temporary glycosuria.* Temporary glycosuria frequently follows an injury to the head, or occurs during convalescence from fevers. In these cases it is thought to be due to temporary inability of the system to oxidize sugar. In the disease called diabetes mellitus, glucose persists in the urine. In mild cases this condition can be controlled by lessening the amount of carbohydrate food, but in severe cases glucose will appear in the urine even when no carbohydrates are eaten. This condition is serious because it means that the body tissues are being oxidized to form glucose.

Indican. — Indican is a potassium salt that is formed from indol. Indol results from the putrefaction of protein food in the

large intestine. It is absorbed by the blood and carried to the liver, which it is thought changes the indol to indican, a less poisonous substance. Traces of indican are found in normal urine, but the presence of it in any amount is abnormal and denotes: (1) excessive putrefaction of protein food in the intestines, or (2) disease of the stomach. (1) Excessive putrefaction may be due to a diseased condition of the intestine that interferes with absorption, to a diet containing too much protein food, or to constipation. (2) In certain diseases of the stomach, food is held until it undergoes fermentative changes.

Acetone. — Acetone is a volatile substance that is thought to be the result of incomplete oxidation of fats and possibly of proteins. It is found in the urine of individuals suffering from defective metabolism, and in the urine of normal individuals during periods of fasting.

Casts. — In some abnormal conditions the kidney tubules become lined with substances which harden and form a mould or cast inside the tube. Later these casts are washed out by the urine, and their presence in urine can be detected by the aid of a microscope. They are named either from the substances composing them or from their appearance. Thus there are (1) pus casts, (2) blood casts, (3) epithelial casts from the walls of the tubes, (4) granular casts from cells which have decomposed and form masses of granules, (5) fatty casts from cells which have become fatty, and (6) hyaline casts which are formed from coagulable elements of the blood.

Calculi. — Deposits of solid matter that have been precipitated from the urine are called urinary calculi or stones. These vary in size, shape, and composition; the size and shape being determined largely by their composition and location. They may be formed in any part of the urinary tract from the tubules to the external orifice of the urethra. The causes which lead to their formation are (1) an increase in the slightly soluble constituents of the urine, (2) a decrease in the amount of water secreted, and (3) abnormally acid or abnormally alkaline urine.

Pus. — In suppurative conditions of any of the urinary organs pus cells are present in the urine.

Blood. — In cases of acute inflammation of any of the urinary organs, of tuberculosis, of cancer, and of renal stone, blood may

be found in the urine. If present in large quantity, the urine is deep red, and this condition is known as hematuria.

Toxicity of urine. — As urine is the medium by which the body gets rid of toxic material, it follows that urine itself is toxic, and must be eliminated, else a condition of toxemia will result. This condition is called uremia, because it was thought that the symptoms of poisoning were due to the retention of urea in the body. It is now believed that while urea is poisonous, it is only one of several substances that renders urine toxic. During illness the kidneys always try to eliminate any poisonous substances that find their way into the blood, whether these substances result from defective metabolism or from bacterial activity. This accounts for the fact that after a severe illness the kidneys are often left in a damaged condition.

SUMMARY

- **Wastes of Cell Metabolism**
  - 1. Soluble salts
    - Nitrogenous salts, *e.g.*, urea.
    - Inorganic salts, *e.g.*, sodium chloride.
  - 2. Liquid — water.
  - 3. Gas — carbon dioxide.
  - 4. Solids — waste materials from food.
- **Excretory Organs**
  - Lungs.
  - Kidneys.
  - Alimentary Canal.
- **Urinary System**
  - **Kidneys** (2) — secrete urine.
  - **Ureters** (2) — ducts which convey urine from kidneys to bladder.
  - **Bladder** (1) — reservoir for urine.
  - **Urethra** (1) — tube through which urine is voided.
- **KIDNEYS**
  - **Location**
    - Posterior part of lumbar region, behind peritoneum.
    - Placed on either side of spinal column and extend from upper border of twelfth thoracic to third lumbar vertebra.
  - **Capsule and supports**
    - Covered by tough envelope of fibrous tissue.
    - Supported by pressure and counter-pressure of neighboring structures.
  - **Size and shape**
    - Four and one-half inches long, two and one-half inches broad, one and one-half inches thick.
    - Weight, four and one-half ounces (130 gms.).
    - Bean-shaped, tubular glands.
    - Concave side toward spine, convex side outward.
    - Hilum — depression near centre of concave side serves for vessels to enter and leave

- **KIDNEYS**
  - **Anatomy of the kidney**
    - **Pelvis** — upper expanded end of ureter.
    - **Calyces** — cup-like cavities of the pelvis that receive papillæ of pyramids.
    - **Cortex** — outer, more solid portion.
    - **Medulla** — inner, striated portion.
    - **Columns of Bertini** — interpyramidal extensions of cortical substance.
    - **Uriniferous tubules**
      - Begin as hollow globes or capsules in the cortex of kidney, and after a very irregular course open into straight collecting tubes which pour their contents into calyces of pelvis.
    - **Pyramids**
      - Cone-shaped masses in the medullary portion of the kidney. Vary in number.
      - **Bases** directed toward cortex.
      - **Papillæ** — apices of the pyramids, directed toward pelvis.
      - Consist of uriniferous tubules, blood-vessels, and lymphatics, held together by connective tissue.
    - **Renal corpuscles**
      - Minute tufts of capillaries — glomeruli — in the cortical portion of kidneys which are surrounded by inverted capsule of uriniferous tubule.
    - **Blood supply**
      - **Renal artery** — direct from aorta.
      - Enters hilus of kidney, divides into many branches.
      - **Arterial arches**
        - Lateral branches at the level of the base of the pyramids.
        - 1. Send branches to cortex (cortical).
        - 2. Send branches to pyramids.
      - **Venous arches**
        - Lateral branches at level of base of pyramids.
        - Receive blood from cortex.
        - Receive blood from pyramids.
      - Veins empty into renal vein, leave kidney at hilus, and empty into inferior vena cava.
      - **Note** — Blood from renal artery serves for purposes of nourishment of kidney and purposes of excretion.
    - **Nerves and lymphatics**
      - Nerves from sympathetic and central nervous system.
      - Many are vasomotor, and by regulating size of blood-vessels influence blood pressure.
      - Well supplied with lymphatics.
  - **Function**
    - **Secretion of urine**
      1. Process of mechanical filtration. Water and saline elements are filtered from the blood during the circulation through the glomeruli.
      2. Secretory action of the cells lining the uriniferous tubules. Urea and other foreign substances are separated from the blood during the circulation through the plexus of capillaries which surrounds the tubules.

Ureters
- Excretory ducts. Extend from kidneys to bladder.
- Consist of expanded portion called pelvis and duct.
- Size of goose-quill. 10–12 in. long.
- **Three coats**
  1. Mucous — lining.
  2. Muscular
     - Inner, longitudinal layer.
     - Outer, circular layer.
  3. Fibrous — carries blood-vessels and nerves.
- **Function**
  - Connect kidneys with bladder.
  - Passageway for urine.

Bladder
- Hollow muscular organ.
- Situated in pelvic cavity behind the pubes
  - in front of rectum in male.
  - in front of anterior wall of vagina and neck of uterus in female.
- Freely movable. Held in position by ligaments.
- Size, shape, and position depend upon age, sex, and whether bladder is full or empty.
- Fundus — widest part.
- Cervix — where the bladder becomes continuous with the urethra.
- **Four coats**
  1. Mucous — lining.
  2. Areolar — connects mucous and muscular.
  3. Muscular
     - Inner layer — longitudinal.
     - Middle layer — circular.
     - Outer layer — longitudinal.
  4. Serous — partial covering derived from peritoneum.
- **Function**
  - Serves as a reservoir for the reception of urine.
  - When moderately distended, holds about one pint.

Urethra
- Membranous canal, extends from the bladder to the meatus urinarius. $1\frac{1}{2}$ in. long and $\frac{1}{4}$ in. in diameter in female.
- Behind symphysis pubis, and embedded in the anterior wall of vagina.
- **Three coats**
  1. Mucous — lining.
  2. Submucous — supports network of veins.
  3. Muscular
     - Inner — longitudinal.
     - External — circular.
- Meatus urinarius — external orifice located between clitoris and vagina.

Micturition
- Act of expelling urine from bladder.
- Occurs as result of irritation due to accumulation of urine in bladder.
- Involuntary act — can be controlled by voluntary effort.

Retention
- Failure to void urine.
- Due to
  1. Dulling of the senses.
  2. Nervous contraction of urethra.
  3. Some obstruction in urethra or neck of bladder.
- May be accompanied by overflow or constant voiding of small amounts.

Suppression — Failure of the kidneys to secrete urine.

Urine
- **Transparency** — depends on absence or presence of mucus and pus.
- **Color** — depends on concentration. Relative amounts of water and solids.
- **Reaction** — usually acid.
- **Specific gravity** — average 1.020. Depends on concentration.
- **Quantity**
  - Average 40 to 50 ounces.
  - Increased by
    - Ingestion of large amount of liquid.
    - Action of diuretics.
    - Nervousness.
    - Diseases
      - Diabetes insipidus.
      - Diabetes mellitus.
      - Hysteria.
  - Decreased by
    - Ingestion of small amount of liquid.
    - Vomiting, diarrhœa.
    - High fever.
    - Disease of kidneys.
    - Increased action of skin.

Composition of Urine
- Water, 95 per cent
- Soluble Salts 5 per cent
  - **Organic** about 3.7
    - **Urea** (2 per cent of total solids).
    - Purin bodies
      - Uric acid.
      - Xanthin.
      - Hypoxanthin.
    - Creatinin.
    - Hippuric acid.
    - Other substances.
  - **Inorganic,** about 1.3
    - Sodium chloride.
    - Sulphates.
    - Phosphates.
    - Salts of
      - Potassium.
      - Ammonium.
      - Magnesium.
      - Calcium.
    - Other substances.

Urea	End-product resulting from metabolism of proteins. Average excreted in twenty-four hours — 1 ounce. About 0.028 per cent present normally in blood and tissues.	
	Increased by	Diet rich in proteins. Strenuous exercise — hot baths. Some diseases.
	Decreased by	Small amount of protein food. Excessive vomiting, free perspiration. Diseases that interfere with elimination.
Purin bodies	Uric acid Xanthin Hypoxanthin	End-products resulting from metabolism of nucleoproteins of food and tissues.
Creatinin	It is probably an end-product of the metabolism of protein tissue.	
Hippuric acid	Chemical method of defence against toxic substances. Digestion of fruits and vegetables give rise to toxic acids, *e.g.*, benzoic acid. Benzoic acid plus glycocoll → hippuric acid.	
Salts	Derived from food eaten. Derived from neutralization of acids. Sodium chloride is most abundant.	
Abnormal constituents	Albumin. Glucose. Indican. Acetone.	Casts. Calculi. Pus. Blood.

CHAPTER XVIII

THE SKIN; APPENDAGES OF THE SKIN. BODY HEAT; REGULATION OF HEAT. VARIATIONS IN TEMPERATURE

THE SKIN

Functions. — The skin is not, like the kidneys, set apart to perform one special function. It serves: (1) as a protective covering for the deeper tissues lying beneath it, (2) as a sense organ, (3) as an excretory organ, (4) as an important organ in heat regulation, and (5) as a respiratory organ.

Structure. — It consists of two distinct layers: —

(1) Epidermis; scarf skin, or cuticle.

(2) Derma; cutis vera, or corium.

Epidermis. — The epidermis is a stratified epithelium, composed of a number of layers of cells. It varies in thickness from $\frac{1}{240}$ inch (0.104 mm.) to $\frac{1}{24}$ inch (1.04 mm.), being thickest on the palms of the hands and on the soles of the feet, where the skin is most exposed to friction, and thinnest on the ventral surface of the trunk, and the inner surfaces of the limbs. It forms a protective covering over every part of the true skin, upon which it is closely moulded.

It is roughly divisible into two layers: —

(1) Superficial, or Horny.
(2) Germinative, or Malpighian.

(1) The **superficial** layer consists of three strata of cells, which are practically dead, and are constantly being shed and renewed from the cells of the germinative layer.

(2) The **germinative** layer consists of soft protoplasmic cells.

The growth of the epidermis takes place by the multiplication of these cells. As they multiply they push upward toward the surface those previously formed. In their upward progress

they undergo a chemical transformation, and the soft protoplasmic cells become converted into the flat scales which are constantly being rubbed off the surface of the skin. The pigment in the skin of the negro, as well as that of the nipple in white races, is found in the deepest cells of the germinative layer.

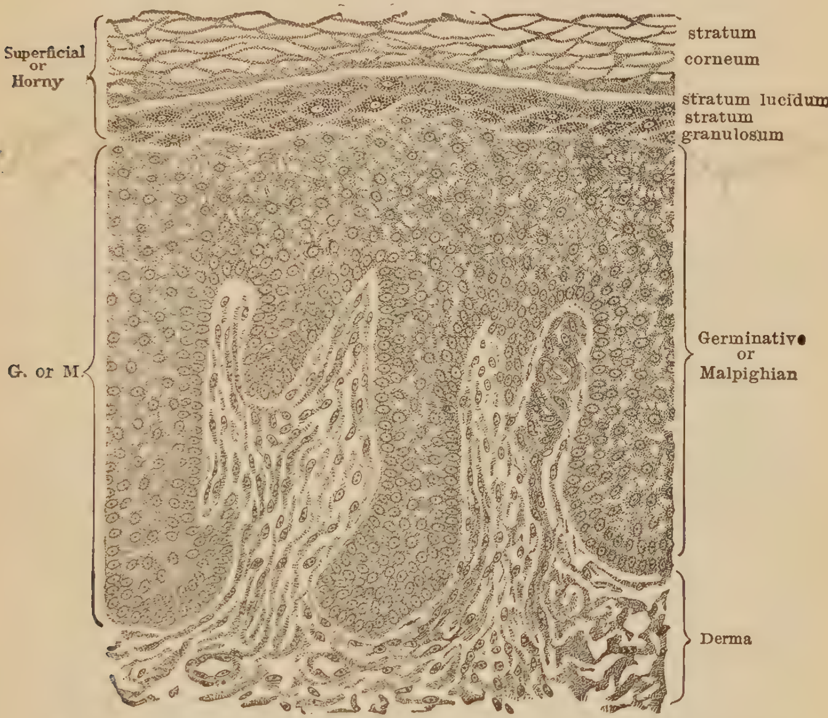


FIG. 188. — VERTICAL SECTION THROUGH THE SKIN OF THE PALMAR SIDE OF THE FINGER, SHOWING TWO PAPILLÆ (ONE OF WHICH CONTAINS A TACTILE CORPUSCLE) AND THE DEEPER LAYER OF THE EPIDERMIS. (Schäfer.)

No blood-vessels pass into the epidermis; it, however, receives fine nerve-fibrils between the cells of the germinative layer.

Derma. — The derma is a highly sensitive and vascular layer of connective tissue. It is described as consisting of two layers: —

(1) Upper, or papillary layer.
(2) Deeper, or reticular layer.

(1) The surface of the **papillary** layer is increased by protrusions in the form of small conical elevations, called papillæ, whence this layer derives its name. They project up into the epidermis,

which is moulded over them, and contain for the most part looped blood-vessels, but they also contain the terminations of nerve-fibres in the shape of little bodies called *tactile corpuscles*.

The papillæ seem to exist chiefly for the purpose of giving the skin its sense of touch, being always well developed where the sense of touch is exquisite. They are specially large and numerous on the palm of the hand and the tips of the fingers, and on the corresponding parts of the foot.

(2) The **reticular** layer of the corium is a continuation of the papillary layer, there being no real division between them. It is made up of bundles of white fibrous and elastic tissue.

The derma is attached to the parts beneath it by a layer of areolar tissue, here named *subcutaneous*, which layer, with very few exceptions, contains fat. The connection in some parts is loose and movable, as on the front of the neck; in others, close and firm, as on the palmar surface of the hand and the sole of the foot.

Blood-vessels. — The blood-vessels of the skin are found in the derma only. They form a network of capillaries in which the vessels are very close to each other, and send branches to the papillæ and glands of the skin. The capillaries of the skin are capable of holding from one-half to two-thirds of the blood contained in the body. The amount of blood they contain is dependent on their caliber, and this is regulated largely by the vasomotor nerves.

Nerves. — The skin is provided with a great variety of nerves.[1] They are classified as follows: —

(1) Vasomotor nerves, which are distributed in the walls of the blood-vessels.

(2) Two sets of nerves concerned in the temperature sense, which terminate in the hot and cold spots of the skin.

(3) The nerves concerned in the sense of touch or pressure.

(4) Nerves which are stimulated by pain.

(5) Motor nerves, which are derived from the sympathetic system and distributed to the glands and the arrector muscles.

Because of the number of afferent nerves which lead from the skin to centres in the brain and spinal cord, nearly every nerve centre in the body may be affected by sensations arising in the skin.

[1] See page 430.

It is for this reason that hydrotherapeutic applications, heat, cold, and counter irritants excite so many and such varied reflexes.

THE APPENDAGES OF THE SKIN

The appendages of the skin are the nails, the hair, the sebaceous glands, the ceruminous glands, and the sudoriferous or sweat glands.

The nails. — The nails are composed of clear, horny cells of the epidermis, joined so as to form a solid, continuous plate. Each nail is convex on its outer surface, concave on its inner side, and closely adherent to the underlying derma, which is modified to form what is called the bed, or *matrix*, of the nail. At the hinder part of the bed of the nail the skin forms a deep fold, in which is lodged the root of the nail.

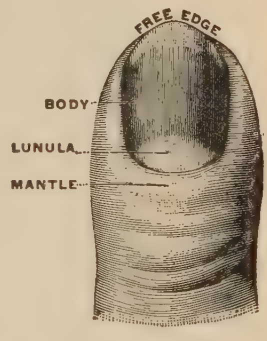


FIG. 189. — THUMB-NAIL. (Gerrish.)

The growth of the nail is accomplished by constant multiplication of the soft cells in the germinative layer at the root. These cells are transformed into dry, hard scales, which unite into a solid plate, and the nail, constantly receiving additions from below, slides forward over its bed and projects beyond the end of the finger. When a nail is thrown off by suppuration or torn off by violence, a new one will grow in its place provided any of the cells of the germinative layer are left.

The hair. — The hair is a growth of the epidermis, developed in little pits, the hair-follicles, which extend downward into the deeper part of the true skin, or even into the subcutaneous tissue. The hair grows from the bottom of the little pit or follicle. The part which lies within the follicle is known as the root, and that portion which projects beyond the surface of the skin is called the shaft or stem. The substance of the hair is composed of coalesced horny cells, arranged in different layers, and we usually distinguish three parts in the stem or shaft of a hair: —

(1) *Cuticle* — an outer layer of delicate, scale-like cells.

(2) *Fibrous substance* — a middle portion, formed of elongated cells. These cells and the intercellular spaces contain a varying

amount of pigment, and the color of the hair depends upon the quantity. The gray hair of old age is produced by loss of pigment.

(3) *Medulla* — a central pith formed of round cells.

The root of the hair is enlarged at the bottom of the follicle into a bulb or knob. This bulb is composed of soft-growing cells, and fits over a vascular papilla which projects into the bottom of the follicle. Hair has no blood-vessels but receives nourishment from the blood-vessels of the papilla.

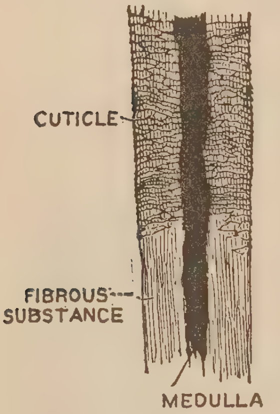


FIG. 190. — PIECE OF HUMAN HAIR. (Highly magnified.)

Growth of hair. — Hair grows from the bottom of the follicle by multiplication of the soft cells which cover the papilla. These cells become elongated to form the fibres of the fibrous portion, and as they are pushed to the surface, they become flattened and form the cuticle. If the scalp is thick, pliable, and moves freely over the skull it is favorable to the growth of hair. A thin scalp that is drawn tightly over the skull tends to constrict the blood-vessels, lessen the supply of blood, and cause atrophy of the roots of the hair by pressure. In such cases massage of the head loosens the scalp, improves the circulation of the blood, and usually stimulates the growth of hair.

With the exceptions of the palms of the hands, the soles of the feet, and the last phalanges of the fingers and toes, the whole skin is studded with hair. The hair of the scalp is long and coarse, but most of the hair is very fine and extends only a little beyond the hair follicle.

Arrector muscles. — The follicles containing the hairs are narrow pits which slant obliquely upward, so that the hairs they contain lie slanting on the surface of the body. Connected with each follicle is a small muscle called the arrector muscle. It is composed of bundles of plain muscular tissue which pass from the surface of the true skin, *on the side to which the hair slopes,* obliquely downward, to be attached to the bottom of the follicle. When these muscles contract, as they will under the influence of

cold or terror, the little hairs are pulled up straight, and stand "on end"; the follicle also is dragged upward, and in this way the roughened condition of the skin known as "gooseflesh" is produced.

Sebaceous glands. — The sebaceous glands are small, saccular glands, which lie between the hairs and their arrector muscles.

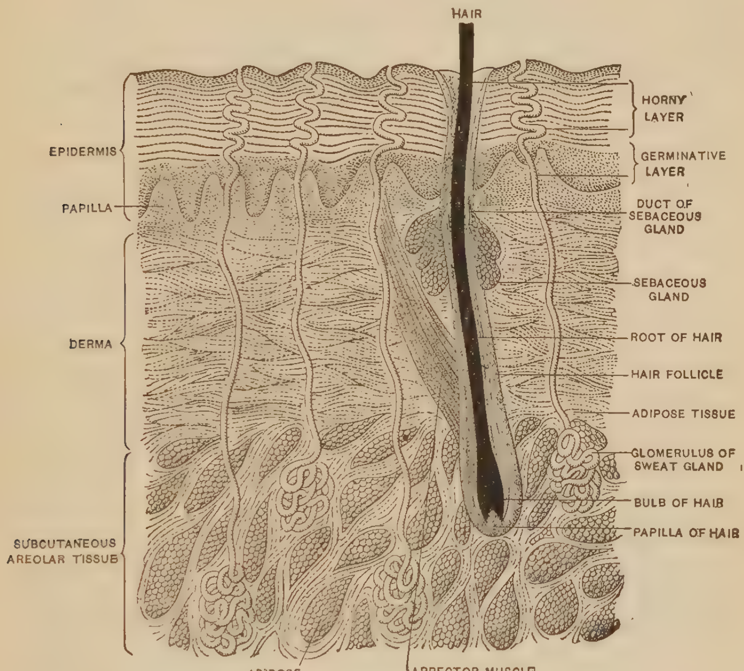


FIG. 191. — VERTICAL SECTION OF THE SKIN, SHOWING SEBACEOUS GLANDS, SWEAT-GLANDS, HAIR AND FOLLICLE, ALSO ARRECTOR MUSCLE. (Gerrish.)

They occur everywhere over the skin surface, with the exception of the palms of the hands and the soles of the feet.

Each gland consists of a collection of small tubes overspread with a network of capillaries. From the gland a small duct ascends, and opens either upon the surface of the skin, or as is more common, into a hair follicle. Their size is not regulated by the length of the hair. Thus, some of the largest are found on the nostrils and other parts of the face, where they often become enlarged with pent-up secretion.

Sebum. — The secretion of the sebaceous glands is called sebum.

It contains fat, soaps, epithelial cells, albuminous matter, and inorganic salts. It serves to remove waste matters and is classed as an excretion, but its more important purposes are to keep the skin and hair soft and pliable, and to form a protective layer on the surface of the skin. An accumulation of this sebaceous matter upon the skin of the fœtus furnishes the thick, cheesy, oily substance called the *vernix caseosa.*

Ceruminous glands. — The skin lining the external auditory canal contains modified sweat-glands called ceruminous glands. They secrete a yellow, pasty substance resembling wax which is called cerumen.

Sweat-glands. — The sweat-glands are simple, convoluted, tubular glands with the blind ends coiled into little balls which are lodged in the true skin or subcutaneous tissue; from the ball the tube is continued as the excretory duct of the gland up through the true skin and epidermis, and finally opens on the surface by a slightly widened orifice called a pore. Each tube is lined by a secreting epithelium continuous with the epidermis. The coiled end is closely invested by a meshwork of capillaries, and the blood in the capillaries is only separated from the cavity of the glandular tube by the thin membranes which form their respective walls. The secretory apparatus in the skin is somewhat similar to that which obtains in the kidneys; in the latter the blood-vessels are coiled up within the tube, while in the skin the tube is coiled up within the meshwork of blood-vessels.

FIG. 192. — COILED END OF A SWEAT-GLAND. *a*, the coiled end; *b*, the duct; *c*, network of capillaries, inside which the sweat-gland lies.

The sweat-glands are abundant over the whole skin, but they are largest and most numerous in the axillæ, the palms of the hands, soles of the feet, and the forehead.

Perspiration, or sweat. — The sweat is a watery, colorless liquid,

slightly turbid, of a salty taste, with a distinctive odor and an alkaline reaction, although when first secreted it may be acid. It is an excretion, the chief normal constituents of which are water, salts, fatty acids, a small quantity of carbon dioxide, and a slight amount of urea. In various forms of kidney disease urea may be present in considerable quantity, the skin supplementing to a certain extent the deficient work of the kidneys.

Quantity of perspiration or sweat. — Under ordinary circumstances, the perspiration that we are continually throwing off evaporates from the surface of the body without our becoming sensible of it, and is called *insensible perspiration*. When more sweat is poured upon the surface of the body than can be removed at once by evaporation, it appears on the skin in the form of drops, and we then speak of it as *sensible perspiration*.

The average amount discharged during twenty-four hours is about one quart (1 litre), but it may be increased to such an extent that even more may be discharged in an hour. The secretion of sweat is *increased* by: (1) a dilute condition of the blood such as results from drinking large quantities of liquids, (2) increased temperature or humidity of the atmosphere, (3) exercise, (4) pain, (5) mental excitement or nervousness, (6) dyspnœa, (7) use of diaphoretics, (8) certain diseases, such as tuberculosis, acute rheumatism, and malaria, (9) use of electricity to stimulate the secretory nerves.

The secretion of sweat is *decreased* by: (1) voiding of a large quantity of urine, (2) cold, (3) diarrhœa, (4) certain drugs, and (5) certain diseases, such as fevers, diabetes, and some cases of paralysis.

Activity of the sweat-glands. — Experimental work with animals has led some observers to believe (1) that there is a definite sweat centre in the brain. The exact location of this centre has not been determined, but reasoning from analogy it seems probable that it may be located in the medulla. (2) That definite secretory nerves from this centre are distributed to the sweat-glands.

The activity of these glands may be influenced by external heat, dyspnœa, muscular exercise, and the action of various drugs. In all such cases the effect is supposed to be the result of either direct stimulation of the nerve-endings in the glands, or indirect stimulation through the nerve centres. The common cause of

profuse sweating is a high external temperature or muscular exercise. It is known that the high temperature acts upon the sensory cutaneous nerves and stimulates the sweat fibres indirectly through the nerve centres, and possibly directly by increasing the irritability of the nerve-endings.

Excretory function of the skin. — While sweat is an excretion, its value lies not so much in the elimination of waste matter as in the loss of body heat by the evaporation of water. Each gram of water requires about 0.5 calorie to cause it to evaporate, and this heat is taken from the body. This loss of heat helps to balance the production of heat that is constantly taking place.

BODY HEAT

From the standpoint of heat production animals may be divided into two great classes: —

(1) **Constant temperature** [1] animals, or those whose temperature remains practically constant whether the surrounding air is hotter or cooler than the body. The term warm-blooded is also applied to this class. It includes human beings.

(2) **Variable temperature** [2] animals, or those whose temperature varies with that of the surrounding medium. This class is also described as cold-blooded. The human fœtus is cold-blooded.

The great difference between these two classes is in their reactions to external temperature. A cold environment reduces the temperature of the cold-blooded creature, reduces the metabolism of all its tissues, and thus reduces its heat production. The warm-blooded animal reacts in precisely the opposite way. Since his temperature remains constant, his heat production must increase in order to neutralize the effect of cold surroundings.

Production of heat. — Heat in the body is produced by such chemical changes going on in the tissues as are associated with oxidation. Friction is a minor source of heat, *i.e.*, that caused by the movements of the muscles, the circulation of the blood, and the ingestion of warm food.

Where heat is produced. — *Wherever metabolic changes are taking place, there heat is set free.* These changes take place more rapidly in some tissues than in others, and in the same tissues

[1] Homothermous. [2] Poikilothermous.

at different times. The muscles always manifest a far higher rate of activity than the connective tissues, and consequently the former evolve a larger proportion of the bodily heat than the latter. We might liken the different tissues of the body to so many fireplaces stored with fuel, the fuel in some of the fireplaces being more easily ignited and burning more rapidly than in others. The muscles and the secreting glands, especially the liver, are supposed to be the main sources of heat, as they are the seats of a very active metabolism.

Loss of heat. — The heat thus continually produced is as continually leaving the body by the skin and the lungs, and by the urine and feces which are at the temperature of the body when voided. It has been calculated that in every 100 parts, about: —

73.0 per cent is lost by conduction and radiation.
14.5 per cent is lost by evaporation.
10.7 per cent is lost by expired air: —
  (*a*) vaporization of water, 7.2 per cent.
  (*b*) warming of air, 3.5 per cent.
1.8 per cent is lost by urine and feces.

The temperature and humidity of the atmosphere may cause considerable difference in the per cents given above. A low temperature will increase the loss of heat by radiation and decrease that by evaporation. A high temperature will decrease the loss of heat by radiation and increase that by evaporation, owing to the greater production of sweat. From the above figures it is evident that the skin is the important factor in getting rid of body heat. This is due: (1) to the large surface offered for radiation, conduction, and evaporation; and (2) to the large amount of blood which it contains.

Distribution of heat. — The blood, as we know, permeates all the tissues in a system of tubes or blood-vessels. Wherever oxidation takes place and heat is generated, the temperature of the blood circulating in these tissues is raised. Wherever, on the other hand, the blood-vessels are exposed to evaporation, as in the moist membranes in the lungs, or the more or less moist skin, the temperature of the blood is lowered. The gain and loss of heat balance one another with great nicety, and the blood, circulating rapidly, now through warmer, and again through cooler, tubes, is kept at a uniform temperature of about 100°F. (37.8°C.).

In this way the whole body is warmed in somewhat the same way as we warm a house, the warm blood in the blood-vessels heating the tissues, as the hot water in the hot-water pipes heats the rooms in water-heated dwellings.

THE REGULATION OF BODY HEAT

The regulation of body heat is due to the maintenance of a certain balance between heat production and heat dissipation. To many physiologists it has seemed reasonable to suppose that this balance was controlled by a definite set of heat nerves connected with heat centres in the brain. While such an apparatus may exist the evidence in favor of it is not convincing, and the conservative view is that the control of heat production and heat dissipation is effected by the coördinated activities of different centres plus such voluntary means as (1) the regulation of muscular exercise and diet, (2) the use of suitable clothing, and (3) the use of hot and cold baths.

The involuntary regulation of the body temperature is effected chiefly through the following centres: —

Heat Production	1. The quantity and character of food. 2. The motor nerve centres and the motor fibres to the skeletal muscles.
Heat Dissipation	1. The respiratory centre. 2. The sweat centres and sweat nerves. 3. The vaso-constrictor centres and nerves distributed to the skin.

Heat production. — (1) In a previous chapter we described how the oxidation of different foodstuffs produced varying amounts of heat. (2) The motor nerve-fibres which are distributed to the skeletal muscles are indirectly stimulated by cold. It causes the muscles to contract and speeds up the processes of oxidation.

Heat dissipation. — (1) The stimulation of the sensory nerves of the skin that are affected by cold influences the respiratory centre, increases the rate of the respirations, and consequently increases the loss of heat. In man respiration plays only a small part in heat regulation, but in animals that do not perspire, respiration is an important means of regulating the temperature.

(2) When the external temperature is high, the nerve-endings which respond to heat are stimulated, and these impulses are

transmitted over sensory nerves to the nerve centres controlling the motor nerves of the sweat-glands. The motor nerves stimulate the activity of the sweat-glands, and an increased amount of sweat is poured out upon the surface of the body. An increased amount of heat is required to vaporize this sweat, and thus heat is lost. Excessive humidity interferes with the evaporation of water, and thus interferes with the loss of heat; hence the discomfort experienced on hot, humid days.

(3) The sensory nerves which are stimulated by heat not only transmit impulses that stimulate the sweat-glands to activity, but at the same time transmit impulses that result in the depression of the vaso-constrictor nerves of the arterioles of the skin. In consequence the arterioles dilate and more blood is sent to the surface to be cooled. When the external temperature is low, the sensory nerve-endings which are stimulated by cold transmit impulses which result in stimulation of the vaso-constrictors, and consequent contraction of the arterioles of the skin. This lessens the amount of blood in the skin arterioles, and lessens the amount of heat lost.

The voluntary regulation of body temperature is effected by the following means: —

By muscular exercise and diet. — Muscular contractions give rise to heat, therefore muscular activity is used as a means to counteract the effects of external cold. On the other hand, muscular activity does not increase the temperature in hot weather to any marked extent. This is accounted for by the fact that when muscular exertion causes the blood to circulate more quickly than usual, the blood-vessels in the skin dilate, the sweat-glands at the same time are excited to pour out a more abundant secretion, and the heated blood passing in larger quantities through the cutaneous vessels (which are kept well cooled by the evaporation of the perspiration), the general average temperature of the body is maintained.

During digestion heat is produced partly by the peristaltic action of the intestines, and partly by the activity of the various digestive glands (particularly the liver). The quantity of food eaten, and the relative amount of heat-producing food, influence the temperature of the body. In cold weather an increase in food (usually accompanied by an increase of fats) serves to replace the

greater amount of heat lost. When muscular exercise is impossible, as in infants, an increase in fats serves the same purpose as exercise in a healthy adult.

By clothing. — By clothing we can aid the functions of the skin and the maintenance of heat; though, of course, clothes are not in themselves sources of heat. Clothing of any kind captures a layer of warm and moist air between it and the skin, and thus diminishes greatly the loss by evaporation and radiation. In considering the heat value of clothing the important properties are: (1) whether it is loosely or tightly woven, (2) its thickness, and (3) its color.

(1) Materials that are loosely woven will be warmer than those that are tightly woven, because the meshes in a loosely woven material are capable of holding air, which is a poor conductor of heat, and thus prevents radiation.

(2) Thick material does not allow cold air to penetrate to the skin.

(3) Dark-colored materials absorb heat to some extent, hence they are warmer than light-colored textiles. Thick, porous materials are used to keep the body warm. Wool has an additional advantage, as evaporation takes place more slowly from it than from linen, cotton, or silk. Thin and very porous materials help to keep the body cool, because they allow the air to penetrate to the skin, and thus assist the evaporation of sweat.

Hot baths. — The primary effect of a hot bath is to prevent radiation of heat from the surface of the body, and some increase in temperature may result. If the bath is not continued for too long a time, this effect is counteracted by the increased perspiration that follows.

Cold baths. — The primary effect of a cold bath is similar to the effect of cold air. The cold contracts the arterioles of the skin, drives the blood to the interior, and increases oxidation. If the bath is a short one and is followed by friction, the reaction is for the arterioles to dilate, the heated blood is sent to the surface, the circulation is quickened, and there is a consequent loss of heat. In health the gain in heat is usually balanced by the loss of heat, and the purpose of a cold bath is to exercise the arterioles and stimulate the circulation. If the bath is continued for some time, the temperature of the skin, and of the muscles lying beneath, is

reduced, and either the heat-producing processes may be checked and a loss of temperature result; or shivering may intervene. In this case the muscular contractions and constriction of the blood-vessels stimulate metabolism and heat production. When cold baths are given for the purpose of increasing heat elimination, friction is used during the bath to prevent shivering. Friction stimulates the sensory nerves of the skin, causes dilatation of the arterioles, and favors the flow of hot blood to the surface, thus decreasing the sensation of cold and increasing heat elimination. If properly given, cold baths stimulate the nervous system, improve the tone of the muscles, including the muscles of the heart and blood-vessels, stimulate the circulation, and favor the elimination of heat.

VARIATIONS IN TEMPERATURE

Normal variations. — The temperature of the human body is usually measured by thermometers placed in the mouth, axilla, or rectum. Such measurements show slight variations, as the temperature in the interior of the body is slightly higher than on the surface of the skin. The average temperature in the rectum [1] is 98.9° F., in the axilla is 98° F., in the mouth is 98.3° F.

Other normal variations depend upon the manner of living, time of eating, age, etc. The lowest temperature is usually in the early morning, it rises slowly during the day, reaches its maximum in the evening, and falls again during the night. This corresponds to the usual temperature ranges in fever, when the minimum is in the early morning, and the maximum is in the evening. Muscular activity and food may cause a slight increase in temperature during the day. Age has some influence. Infants and young children have a slightly higher temperature than adults. It is also true that the heat-regulating mechanism in infants [2] and young children is not so efficient as in adults, consequently they are more subject to changes of body temperature, and these changes are not as significant as they would be with adults. Aged people show a

[1] Rectal temperature is the most reliable; and that by mouth (if properly taken) is almost equally reliable. Axillary temperature has little value.

[2] At birth the heat-regulating mechanism is not "in working order," and during the first few weeks of life infants are not able to regulate their body temperature, hence the importance of keeping them warm. Premature infants are even less able to regulate their body temperature, hence need of special means to keep them warm.

tendency to revert to infantile conditions, and their temperature is usually slightly higher than in middle life.

Abnormal variations. Fever. — The term fever is applied to an abnormal condition, characterized by increased temperature, increased heart-beat, increased respiration, increased tissue waste, and faulty secretion.

Cause. — The exact cause of fever is unknown. It is the result of causes which disturb the balance between heat production and heat elimination. One theory is that toxic substances circulating in the blood or abnormal conditions of the various organs of the body may interfere with the proper functioning of various nerve centres. The toxic substances circulating in the blood may result from faulty metabolism, as in diabetes, gout, etc.; or from the action of bacteria, as in infectious diseases; or from injury to the tissues of a mechanical, thermal, or chemical nature.

Value of fever. — When fever is due to infection by bacteria, the body seems better able to fight the infection if the temperature is elevated. For this reason fever is thought to be a protective measure and antipyretics are not used unless the elevation is extreme, or long continued. In such cases measures must be taken to reduce the temperature, or death may ensue from coagulation of the body proteins.

Subnormal temperature. — In some maladies the temperature falls distinctly below normal. This is due chiefly to diminished metabolism. In cases of starvation the fall of temperature is very marked, especially during the last days of life. The diminished activity of the tissues first affects the central nervous system; the patient becomes languid and drowsy, and finally unconscious; the heart beats more and more feebly, the breath comes more and more slowly, and the sleep of unconsciousness passes insensibly into the sleep of death.

SUMMARY

Skin

- **Functions**
  1. Protective covering for deeper tissues.
  2. As a sense organ.
  3. As an excretory organ.
  4. **Most important** as organ in heat regulation.
  5. As a respiratory organ
     - Small amount oxygen taken in.
     - Small amount carbon dioxide is thrown off.
- **Consists of**
  - **Epidermis** is a stratified epithelium
    1. Superficial or horny
       - a. Stratum corneum
       - b. Stratum lucidum
       - c. Stratum granulosum
       - Practically dead cells being constantly shed and renewed from germinative layer.
    2. Germinative or Malpighian — Soft protoplasmic cells that are constantly multiplying by cell division.
  - **Derma** is a layer of connective tissue
    1. Papillary layer — papillæ are minute conical elevations of the cutis vera. They contain looped blood-vessels and terminations of nerve-fibres called tactile corpuscles.
    2. Reticular layer — Bundles of fibrous and elastic tissue, with network of blood-vessels, lymphatics, and nerves.
- **Blood-vessels** — They are found in derma only. Send branches to papillæ and glands of skin. Capable of holding one-half to two-thirds total amount of blood in body.
- **Nerves**
  1. Vasomotor.
  2. Two sets concerned in temperature sense.
  3. Nerves concerned in sense of touch or pressure.
  4. Nerves stimulated by pain.
  5. Motor nerves from sympathetic system.
- **Appendages**
  - Nails.
  - Hair.
  - Sebaceous glands.
  - Ceruminous glands.
  - Sweat-glands.

Nails
- Consist of clear, horny cells of epidermis.
- True skin forms a bed or matrix for nail.
- Root of nail is lodged in a deep fold of the skin.
- Nails grow from soft cells in germinative layer at root.

Hair
- The hair grows from the roots.
- The roots are bulbs of soft, growing cells contained in the hair follicles.
- Hair follicles are little pits developed in the derma.
- Stems of hair extend beyond the surface of the skin, consist of three layers of cells: (1) cuticle, (2) fibrous substance, and (3) medulla.
- Found all over body, except
  - Palms of the hands.
  - Soles of the feet.
  - Last phalanges of the fingers and toes.
- Arrector muscles are attached to true skin and to each hair follicle.

Sebaceous Glands
- Saccular glands the ducts of which usually open into a hair follicle, but may discharge separately on the surface of the skin.
- Lie between arrector muscles and hairs.
- Found over entire skin surface except
  - Palms of hands.
  - Soles of feet.
- Secrete *sebum*, a fatty, oily substance, which keeps the hair glossy, the skin flexible, and forms a protective layer on surface of skin.

Ceruminous Glands
- Modified sweat-glands.
- Found in skin of external auditory canal.
- Secrete cerumen, a yellow, pasty substance, like wax.

Sweat-glands
- Tubular glands, consist of blind ends coiled in balls, lodged in subcutaneous tissue, and surrounded by a capillary plexus. Secrete sweat and discharge it by means of ducts which open exteriorly. (Pores.)

Sweat
- Watery, colorless, turbid liquid, salty taste, distinctive odor, and an alkaline reaction.
- Consists of water, salts, fatty acids, urea, and carbon dioxide.
- Average quantity, one quart in twenty-four hours.
- Amount increased by
  1. Dilute condition of blood.
  2. Increased temperature or humidity of the atmosphere.
  3. Exercise.
  4. Pain.
  5. Mental excitement or nervousness.
  6. Dyspnœa.
  7. Use of diaphoretics.

Sweat
- Amount increased by
  - 8. Certain diseases
    - Tuberculosis.
    - Acute rheumatism.
    - Malaria.
  - 9. Use of electricity to stimulate secretory nerves.
- Amount decreased by
  - 1. Voiding a large quantity of urine.
  - 2. Cold.
  - 3. Diarrhœa.
  - 4. Certain drugs.
  - 5. Certain diseases
    - Fevers.
    - Diabetes.
    - Some paralyses.

Activity of Sweat-glands
- Controlled by definite secretory nerves leading to centre in brain.
- 1. Direct stimulation of nerve-ending in sweat-glands.
- 2. Indirect stimulation of nerve centres.

Excretory Function
- Importance *not* in elimination of waste substances in perspiration, but because of *heat* needed to cause evaporation of perspiration.

Body Heat
- Animals divided into 2 classes
  - 1. Homothermous or those which have an almost constant temperature.
    Human beings are in this class.
  - 2. Poikilothermous or those whose temperature varies with that of their environment.
    The human fœtus is cold-blooded.
- **Produced by**
  - 1. Chemical changes associated with oxidation.
  - 2. Friction of muscles, blood, etc.
  - 3. Ingestion of warm food.
    Wherever metabolic changes are taking place.
- **Lost by**
  - Skin 87.5 per cent
    - Offers large surface for radiation, conduction, and evaporation of sweat.
    - Contains large amount of blood.
  - Lungs — 10.7 per cent is lost warming the expired air and the evaporation of the water of respiration.
  - Urine and Feces — 1.8 per cent is lost warming the urine and feces.
- **Distributed** — by the blood circulating through the blood-vessels.

Regulation of Body Heat

- Due to maintenance of *balance* between heat production and heat dissipation.
- **Heat Production**
  1. The quantity and character of food.
  2. The motor nerve centres and the motor fibres to the skeletal muscles.
- **Heat Dissipation**
  1. The respiratory centre.
  2. The sweat centres and sweat nerves.
  3. The vaso-constrictor centres and nerves distributed to the skin.
- **Controlled by**
  1. The coördinated activities of all the different nerve centres.
  2. Voluntary means
     - (*a*) Regulation of muscular exercise and diet.
     - (*b*) Use of suitable clothing.
     - (*c*) Use of hot and cold baths.

Variations in Temperature

- **Normal**
  1. Depends on where temperature is taken
     - Mouth.
     - Axilla.
     - Rectum.
  2. Depends on time of day
     - Lowest in early morning.
     - Highest in early evening.
  3. Slightly increased by muscular activity and the digestive processes.
  4. Age. Higher and more variable in
     - Infants, children, and the aged.
- **Abnormal**
  - **Fever**
    - **Symptoms**
      - Increased temperature.
      - Increased pulse.
      - Increased respiration.
      - Increased tissue waste.
      - Faulty secretion.
    - **Cause** — not definitely known.
    - **Value** — thought to help the body to fight infection.
  - **Subnormal** — due to diminished metabolism.

CHAPTER XIX

THE NERVOUS SYSTEM

As brought out in Chapter III in the section on nerve tissue, the structural and functional unit of the nervous system is the neurone. Neurones as there described are large irregular cells with elongated processes, one of which is an axone, and one or more of which are dendrites. (See Figs. 16 and 18.)

The reflex concept. — In the same way that the nervous system may be reduced to a simple unit designated as the neurone, so may all nervous action be reduced to the so-called reflex action. Just as the neurone forms the building stone of the nervous system, so does the reflex circuit form the functional basis of all nervous activity. At least two neurones enter into the formation of a reflex circuit, a receptor or sensory neurone and an effector or motor neurone.

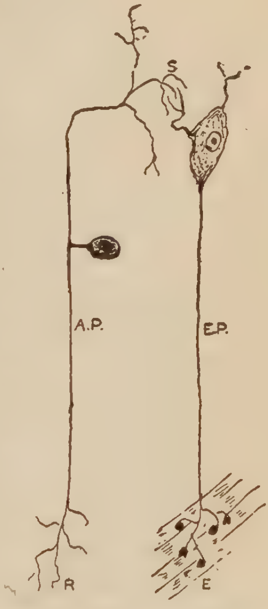


FIG. 193. — A REFLEX CIRCUIT CONSISTING OF A SENSORY AND MOTOR NEURONE. *R*, receptor; *A. P.*, afferent process; *S*, synapse; *E. P.*, efferent process; *E*, effector (muscle). (Burton-Opitz.)

A receptor or sensory neurone is one in which the afferent process ends in a receptor of one kind or another. An effector or motor neurone is one in which the efferent process ends in a muscle or gland cell. Neurones which are interpolated between other neurones are called central or correlation neurones.

A simple reflex circuit may consist in the functioning of a sensory and a motor neurone. Most reflex circuits consist in the functioning of a sensory neurone, a correlation or central neurone, and a motor neurone, or by complexes of each of these.

Synapse. — We conceive each neurone to be a separate entity and not directly connected with other neurones. The fine branches of an axone of one neurone interlace or dovetail with the branches of a dendrite of another neurone, forming a *synapse.* The nerve-impulse travelling through a nerve-cell must cross a microscopic gap at the synapse to enter the next neurone.

Figure 193 illustrates a reflex circuit consisting of a sensory and a motor neurone. Figure 194 illustrates a reflex circuit consisting of a sensory, correlation, and motor neurone.

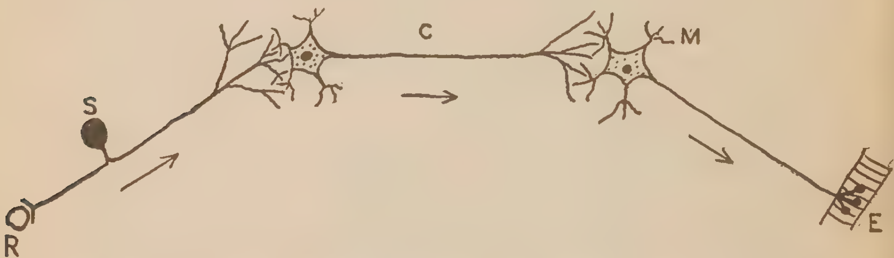


Fig. 194. — A Reflex Circuit Consisting of a Sensory, Correlation, and Motor Neurone. *S*, sensory cell; *C*, central or correlation cell; *M*, motor cell.

On applying an appropriate stimulus to the receptor ending of the sensory neurone, an impulse is generated which passes along the afferent process to the cell-body of the neurone, thence along the efferent process across the synapse through the correlation neurone and across another synapse to an afferent process of the motor neurone, then through the cell-body and an efferent process to the muscle or gland cell where action is produced. (Trace this out in Fig. 194.)

Because of its likeness to a telephone system the peripheral end of the sensory nerve is often called the receptor (telephone transmitter). The processes are called carriers (telephone wires), the synapses and cell-bodies are called adjustors (telephone operators), and the ending in muscle or gland cell an effector (telephone receiver). The receptor receives the stimulus, transforms it to a nerve-impulse, and passes it on to the afferent process. In the adjusting mechanism the nerve-impulse may be transferred across some synapses rather than others for it must be remembered that each neurone forms synapses not simply with one neurone, as in Fig. 194, but probably with many, as in Fig. 195.

Reaction circuit. — When cells in the volitional centres enter into the reflex circuit the resulting action is due to volition or is voluntary, as we say. This reflex circuit is called a reaction circuit. In Fig. 195 the circuit starting at *R* and running through

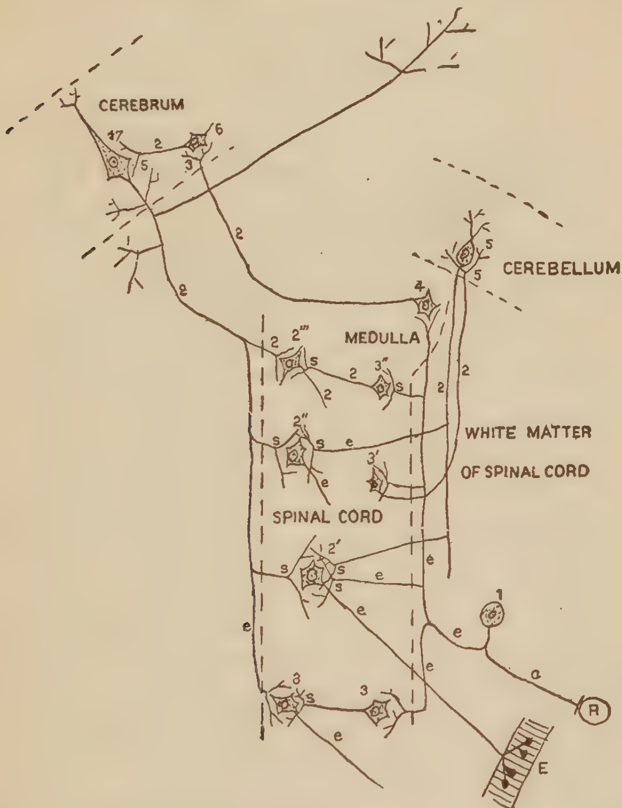


FIG. 195. — DIAGRAM TO ILLUSTRATE SOME REFLEX CIRCUITS OF THE CEREBRO-SPINAL SYSTEM, SHOWING A NUMBER OF CORRELATION AND MOTOR CELLS WITH THEIR SYNAPSES. 1, sensory cell in spinal ganglion; 2, 2′, 2″, 2‴, motor cells; 3, 3′, 3″, 4, 5, 6, 7, correlation cells. *a*, afferent process; *e*, efferent process; *s*, synapse. *R*, receptor; *E*, effector. (Adapted from Huxley-Lee.)

to the cerebral cell may represent a reaction circuit. It will be noted that the difference between a reflex and reaction circuit is found in the fact that in the reflex circuit the voluntary centre is not involved, or the resulting action is involuntary, while in the reaction circuit the voluntary centre is involved and the resulting action is voluntary. Volitional centres lie in the cerebrum.

Classification of reflexes. — In relation to the kind of response brought about by a stimulus, reflex circuits may be classified as: —

(*a*) Simple reflexes in which a single muscle or gland is involved. As an example of this group may be mentioned the corneal reflex.

(*b*) Complex reflexes, in which several muscles or glands are affected, the response remaining perfectly coördinated in spite of the greater number of muscles or glands affected. The patellar reflex and the ankle-jerk are examples of this type.

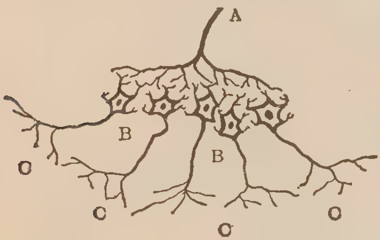


FIG. 196. — DIAGRAM TO ILLUSTRATE A SPREADING REFLEX. *A*, axone dividing into terminal branches which connect with cells *B*, *B*. These cells send their fibres *C*, *C*, *C*, *C*, to supply a number of different muscles.

(*c*) Spreading reflexes in which a large number of different muscles are involved.

(*d*) Tonic or continuous reflexes. The reaction following a stimulus lasts as a rule much longer than the stimulus. In many cases it becomes tonic in character. This result is frequently obtained when the nervous system is extremely irritable as after the administration of strychnine.

(*e*) Clonic or periodic reflexes. In many cases a stimulus may cause a certain reaction to be repeated a number of times at regular intervals. This is frequently true of the acts of sneezing, coughing, hiccoughing, swallowing, and trembling.

(*f*) Association or perception reflexes. For some reactions a definite mental picture is the stimulus to produce the reaction. Thus, the flow of saliva or gastric fluid may be started when well-cooked food is seen or smelled, or a person may find himself yawning when another person yawns.

Nature and speed of nerve-impulses. — The nature of a nerve-impulse is not known. We know that nerve-fibres may be stimulated by several means, and the practical result is similar to the result obtained were the nerve stimulated by the natural physiological impulse. The nerve-fibre has no power to initiate a nerve-impulse, but serves merely as a conductor of the impulse which has been started either in the end organs or in the nerve-cell.

There are four means usually applied to the artificial stimulation of a nerve-fibre, viz. *chemical, thermal, mechanical,* and *electrical.* The latter is the most usual. That the true physiological impulse is none of these can be readily proven. (See any standard work of physiology.)

The best explanation is that the true nature of a nerve-impulse is a *physical molecular vibration* set up either in the nerve-cell or the end organs and transmitted along the nerve-fibre.

Within the body nerve-impulses travel in two directions: (1) from the cell-body to the periphery, and (2) from the periphery to the cell-body.

The speed at which an impulse travels along a nerve-fibre is found to be about 100 to 140 feet (27–33 m.) per second.

It may be interesting to note how very slow a nerve-impulse is when compared with light which travels at the rate of about 186,000 miles per second, and sound which travels about 11,000 feet per second.

Identity of nerve-impulses. — The generally accepted belief is that nerve-impulses are identical in character and vary only in intensity. According to this the impulses carried by a sensory nerve are similar in character to those carried by a motor nerve, and yet the result is different. The result is thought to be determined by the nature of the centre in which a nerve-fibre ends, rather than by the nature of the fibre itself.

Reaction of nerve-endings. — A study of the previous classification[1] shows that the sensory nerve-endings are not all affected by the same stimulus, nor do they react in the same way. Thus some of the sensory nerve-endings are affected by pressure, and others by temperature. The endings of the auditory nerve in the ear are affected only by sound, and the endings of the optic nerve in the eye are affected by sight, though a similar effect may be produced by a blow on the head, or an accident which jars the spinal column.

ANATOMY AND PHYSIOLOGY OF THE NERVOUS SYSTEM

Grouping of neurones. — The nervous system is said to be composed of gray and white matter. The cell-bodies, most of the

[1] See page 36.

dendrites, and the commencement of the axone processes are not scattered promiscuously throughout the body, but are gathered together in certain definite regions or groups. These form the *gray matter* of the brain, spinal cord, and ganglia.

The medullated nerve-fibres found in the brain, spinal cord, ganglia, and also in the nerve trunks distributed to all parts of the body form the *white matter*.

It will therefore be seen that the white matter is made up of the carriers of nerve-impulses, and the gray matter contains the cell-bodies and the synapses where the adjusting of sensory to motor neurones takes place. For purpose of study, it is convenient to classify the nervous system as has been done in Chapter III, or more simply still into: —

Nervous System
- Sympathetic System
  1. Vertebral ganglia.
  2. Collateral ganglia.
  3. Terminal ganglia and plexuses.
  4. Sympathetic ganglia in the brain and cord.
  5. Sympathetic nerves.
- Central Nervous System
  - Spinal cord and spinal nerves.
  - Brain
    - Medulla oblongata.
    - Cerebellum.
    - Pons Varolii.
    - Cerebrum.
  - Cranial nerves.

THE SYMPATHETIC SYSTEM

The sympathetic system consists of four sets of ganglia and the nerves connected with them: —

1. Vertebral or lateral ganglia.
2. Collateral or prevertebral ganglia, and plexuses.
3. Terminal ganglia and plexuses.
4. Sympathetic ganglia in the brain and cord.

The vertebral ganglia. — The vertebral ganglia consist of a chain of ganglia situated on each side of the spinal column, extending from the base of the skull to the coccyx. (See Fig. 197.) They are grouped as cervical, thoracic, lumbar, and sacral, and except in the neck they correspond in number to the vertebræ against which they lie: —

Cervical	3 pairs	Lumbar	4 pairs
Thoracic	10–12 pairs	Sacral	4–5 pairs

They are connected with each other by nerve-fibres called ganglia cords, and with the spinal nerves by branches which are called *rami communicantes*. They are also connected with the viscera and blood-vessels by branches which travel different pathways: (*a*) they pass directly to the viscera; (*b*) they converge to form three main nerve-trunks, called the great splanchnic, the small splanchnic, and the least splanchnic, and then send branches from these trunks to the viscera; (*c*) they join the collateral ganglia and plexuses; (*d*) they join the spinal nerves, by way of the gray rami, and in them reach the part of the body for which they are destined.

The collateral ganglia. — The collateral or outlying ganglia consist of masses of gray matter and their nerves, which are located principally in the thoracic and abdominal cavities. They are connected with the spinal nerves, with the vertebral ganglia, and send branches to the viscera. These branches form plexuses, the most important of which are: (1) the cardiac plexus, located above the heart and supplying it with sympathetic fibres, (2) the solar plexus, located behind the stomach and supplying most of the abdominal viscera, (3) the hypogastric or pelvic plexus, located in the lower part of the abdomen and supplying the viscera of the pelvis.

The terminal ganglia. — The terminal ganglia include all the ganglia situated in the walls of the organs themselves, as for instance those in the walls of the heart, and in the walls of the alimentary canal. These ganglia are directly connected with the collateral ganglia, and in some instances the nerves derived from the collateral plexuses form a secondary or terminal plexus on the organs.

Sympathetic ganglia in the brain and spinal cord. — Sympathetic ganglia are found in the spinal cord and in the medulla, also in connection with a few of the cranial nerves, such as the third and fifth. (See vasomotor centre, page 412.)

Rami communicantes. — The nerve-fibres that connect the vertebral ganglia and the spinal nerves are called rami communicantes. Each connection consists of two rami, one white and the other gray. The white ramus consists of medullated fibres, and these pass from the spinal cord to the sympathetic ganglion. The gray ramus consists of non-medullated fibres that pass from the

sympathetic ganglion to join the spinal nerve, and so reach the part of the body they are to supply.

Plexuses. — The term plexus has been used to designate a network of nerves. It is worthy of special mention because the nerve-fibres arborize with each other, and there is an interchange of fibres between the different nerve-trunks. The advantages of this arrangement are: (1) each nerve is less dependent on the unimpaired condition of any single portion of the nerve-trunk or nerve centre, (2) each nerve has a wider communication with the nerve centres, and (3) any given part of the body is not dependent on one nerve. The various plexuses of the sympathetic system serve all these purposes, and in addition the organs constituting any one system are brought into direct communication with each other. In this way coördination of action is secured.

Distribution of sympathetic nerves. — Nerve-fibres from the sympathetic system are distributed: (1) to the heart, (2) to the involuntary muscles of the blood-vessels, lymphatics, and viscera, (3) to the secretory glands, and (4) to some of the special senses, such as those that regulate the pupil of the eye.

Functions of the sympathetic system. — The sympathetic nervous system exercises a regulatory control over the visceral activities of the body. Our awareness of these actions is limited as most of them are performed quite unconsciously. Nevertheless, they are of enormous importance not only in maintaining our physical welfare, but also as the background of our entire conscious life.

In addition to the power of automaticity possessed in a preeminent degree by the heart and more or less by all visceral muscles, and the chemical control exercised by the internal secretions, the viscera are under nervous control of two sorts, *i.e.*, from the sympathetic nervous system and the central nervous system. Moreover, the nerves which carry impulses from the central nervous system to the viscera are distributed to the viscera through the sympathetic system.

Autonomic nervous system. — The activities controlled by means of the sympathetic ganglia are typically reflex in their character and are relatively independent of the central nervous system. Moreover, they are vegetative or visceral in their nature and are usually described as autonomic. Accordingly, some authorities

use the term autonomic when speaking of the functional side of the sympathetic system, while others apply it to subdivisions of the sympathetic system.[1]

Interdependence of the sympathetic and central nervous system. — From the preceding description it is evident that the sympathetic nervous system cannot be sharply separated either anatomically or physiologically from the central nervous system. Anatomically the fibres which connect the sympathetic ganglia and the spinal nerves form a direct pathway from all of the viscera to the spinal cord and brain. Moreover, many of the viscera are connected with the brain by the cranial nerves.[2] As previously stated the visceral activities are usually performed quite unconsciously, but it frequently happens that they attain consciousness. As an example might be mentioned the hunger contractions of the stomach, or sensations of pain from the viscera of the abdomen, both of which show the functional connection between the sympathetic and central nervous system.

SPINAL CORD

A brief sketch of the lower animals characterized as segmental, is helpful in understanding the structure and functions of the spinal cord. Segmental animals are made up of a number of smaller units which are capable of leading an independent existence. This is made possible by the fact that each segment possesses separate circulatory, digestive, excretory, and nervous systems, so that the segments may be separated without endangering or seriously impairing their life processes. As far as the nervous system is concerned, we find that each segment of these animals is equipped with a centrally placed ganglion from which nerve-fibres extend in all directions to the different tissues of this segment. A stimulus applied to its surface is soon followed by movement or some other motor response. It appears, therefore, that the nervous elements allotted to each segment are arranged in the form of reflex circuits, their centres being grouped in the shape of a central ganglion. The life of the animal as a whole, however, requires a certain *correlation* between the activities of its different segments and a *subordination*

[1] See "Introduction to Neurology" by C. Judson Herrick. [2] See page 421.

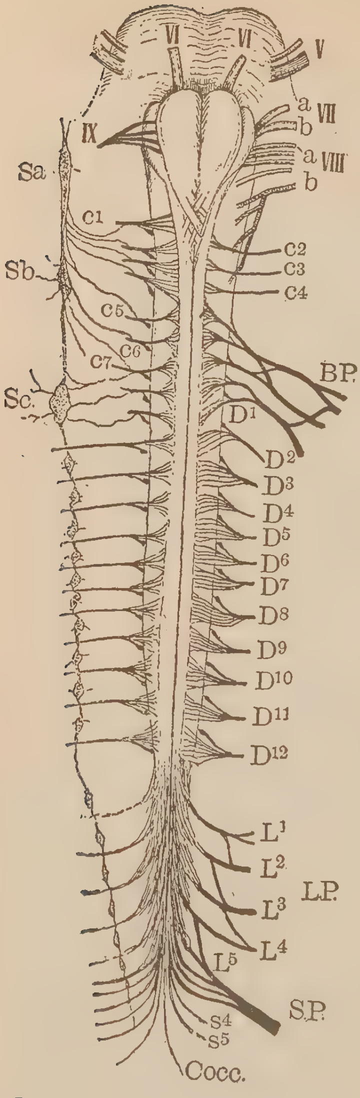


FIG. 197. — VENTRAL VIEW OF BASE OF BRAIN, SPINAL CORD, AND SPINAL NERVES. On the left-hand side the sympathetic chain of ganglia is shown. *V–IX*, cranial nerves. D^1–D^{12}, L^1–L^5, S^4, S^5, and *Cocc.*, spinal nerves, seen emerging from spinal cord by two roots, with ganglia on the dorsal roots. *B.P.*, brachial plexus. *L.P.*, lumbar plexus. *S.P.*, sacral plexus. *Sa*, *Sb*, *Sc*, cervical sympathetic ganglia.

of the latter to the functional necessities of the whole. This end is attained first by intermediary neurones which unite the successive ganglia with one another and secondly, by a hyper-development of the head-ganglion which thus gains a directing control over the others.

A nervous system of this kind is reflex in its nature and forms the basal stem around which the nervous system as it appears in the highest animals is eventually developed. The head-ganglion is comparable to the brain, the segmental ganglia to the spinal cord, and from these parts the afferent and efferent nerves arise.

The spinal cord is that portion of the nervous system lodged within the spinal canal of the vertebral column. It consists of a collection of gray and white substance, extending from the foramen magnum of the skull, where it is continuous with the medulla oblongata, to about the second lumbar vertebra, where it tapers off into a fine thread. Before its termination it gives off a number of fibres which form a tail-like expansion, called the *cauda equina*. (See Fig. 21.)

Structure of the cord. — The spinal cord does not fit closely into the spinal canal, as the brain does in the cranial cavity, but is, as it were, suspended within

it. A series of spaces intervene between its surface and the walls of the canal, affording freedom of movement of the vertebral column without exerting undue tension upon the cord.[1] It diminishes slightly in size from above downward, with the exception of presenting two enlargements in the cervical and lumbar regions, where the nerves are given off to the arms and legs respectively. It varies in length from sixteen to twenty inches (40 to 50 cm.), and has an average diameter of three-fourths of

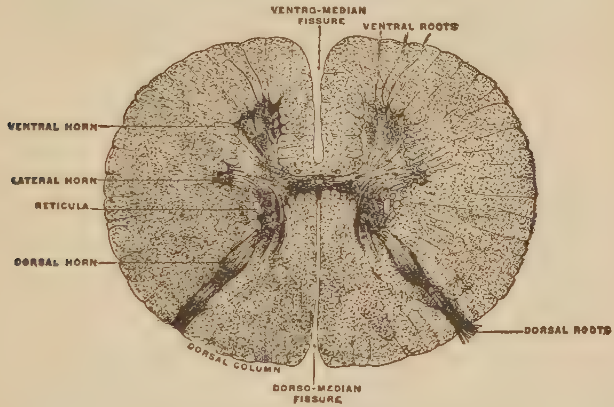


FIG. 198. — TRANSVERSE SECTION OF THE SPINAL CORD AT THE MIDDLE OF THE THORACIC REGION. The neuroglia septum has been removed from between the dorsal columns. (Gerrish.)

an inch (19 mm.). The spinal cord is almost completely divided into lateral halves by a ventral and dorsal fissure; the ventral fissure dividing it in the middle line in front, and the dorsal fissure in the middle line behind. In consequence of the presence of these fissures, only a narrow bridge of the substance of the cord connects its two halves. This bridge, also called the isthmus, is traversed throughout its entire length by a minute central canal. On making a transverse section of the spinal cord, the gray matter is seen to be arranged in the form of an H, and presents on each side a ventral and dorsal horn. The former is short and bulky while the latter is long and slender.

The transverse bar of gray matter found in the isthmus is called the gray commissure, and connects the two lateral masses of gray matter. The white matter is arranged around and between

[1] See Membranes of the Cord.

the gray matter, the proportion of gray and white varying in different regions of the cord. The white matter is composed of medullated nerves, and the gray matter consists of cell-bodies, dendrites, axones, and collaterals, all held together and supported by neuroglia. The white matter may be said to consist of three portions or funiculi, namely, an anterior, a lateral, and a posterior. Each funiculus is in turn divided into smaller segments or fasciculi, commonly called columns or tracts.

Some of these tracts consist of fasciculi made up of fibres which are ascending or sensory. They begin in the gray matter of the

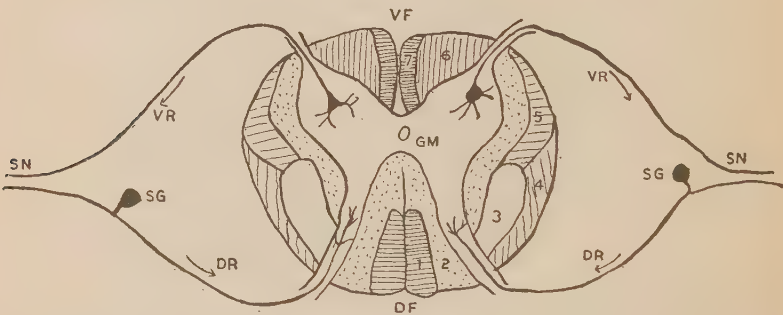


FIG. 199. — CONDUCTION IN SPINAL CORD. 1, 2, fasciculi in dorsal funiculus; 3, 4, 5, fasciculi in lateral funiculus; 6, 7, fasciculi in ventral funiculus of one side of cord. *DF*, dorsal fissure; *DR*, dorsal root; *GM*, gray matter; *SG*, spinal ganglion; *SN*, spinal nerve; *VF*, ventral fissure; *VR*, ventral root. 1, Column of Goll; 2, column of Burdach; 3, crossed pyramidal tract; 4, Flechsig's tract; 5, Gower's tract; 6, ventral ground bundle; 7, direct pyramidal tract. (Burton-Opitz.)

cord, ascend and terminate in the gray matter of the brain, *e.g.*, 1, 2, 4, 5 in Fig. 199. Other tracts consist of fasciculi which are descending or motor. They begin in the gray matter of the brain, descend and terminate in the gray matter of the cord, *e.g.*, 3 and 7.

Other tracts, *e.g.*, 6, are made up chiefly of short ascending and descending fibres beginning in one region of the spinal cord and ending in another.

Membranes of the cord. — The spinal cord is protected and nourished by three membranes which are continuous with the membranes covering the brain and are called by the same names, viz. (1) pia mater, (2) arachnoid, and (3) dura mater. Surrounding these three membranes are three spaces, called respectively (*a*) subarachnoid, (*b*) subdural, and (*c*) epidural.

(1) The **pia mater** closely invests the entire surface of the

spinal cord. The subarachnoid space between it and the arachnoid membrane contains a small amount of cerebrospinal fluid.

(2) The **arachnoid** is a delicate serous membrane placed between the pia mater and the dura mater. The subdural space between these two membranes is very small and contains just enough cerebrospinal fluid to moisten their contiguous surfaces.

(3) The **dura mater** constitutes the outermost and thickest sheath. It does not serve as a periosteum for the vertebral bones, being separated from them by the epidural space which contains a certain quantity of areolar and adipose tissue and a network of veins.

SPINAL NERVES

There are thirty-one pairs of spinal nerves, arranged in the following groups, and named for the region of the vertebral column from which they emerge.

Cervical	8 pairs
Thoracic	12 pairs
Lumbar	5 pairs
Sacral	5 pairs
Coccygeal	1 pair

The first cervical nerve arises from the medulla oblongata and leaves the neural canal between the occipital bone and the atlas. With this one exception the spinal nerves spring from both sides of the spinal cord, and all except the coccygeal pass out through the intervertebral foramina. The coccygeal passes from the lower extremity of the canal.

Mixed nerves. — The spinal nerves consist almost entirely of medullated nerve-fibres, and are called mixed nerves because they contain both sensory and motor fibres. Each spinal nerve has two roots, a ventral root and a dorsal root. The fibres connected with these two roots are collected into one bundle, and form one nerve just before leaving the canal through the intervertebral openings. Before joining to form a common trunk, the fibres connected with the dorsal root present an enlargement, this enlargement being due to a ganglion, or small nerve centre, situated in the intervertebral foramina.

The fibres of the ventral root **arise from the gray matter** in the ventral horn, and are direct prolongations from the cell-bodies

there. Accordingly, all the fibres making up the ventral root are efferent fibres, and convey nerve-impulses from the spinal cord to the periphery.

The fibres of the dorsal root arise from the **cells composing the enlargement** or **ganglion** of the dorsal root; each cell of the ganglion, besides sending a nerve-fibre toward the periphery, sends a branch along the dorsal root up into the gray matter of the dorsal horn, there to form a synapse with the dendrites of other neurones. The fibres making up the dorsal root are afferent fibres, and convey nerve-impulses from the periphery to the spinal cord.

It should be borne in mind that the ventral roots contain only **motor** fibres, and these have their origin within the central nervous system; while the dorsal roots contain only **sensory** fibres, and these fibres always have their origin outside of the cord, *i.e.*, in the spinal ganglia.

The relations of the roots, fibres, and so forth, can be best understood from a study of the accompanying diagrams (Figs. 199 and 200).

Degeneration and regeneration of nerves. — Since the cell-body is essential for the nutrition of the whole cell, it follows that if

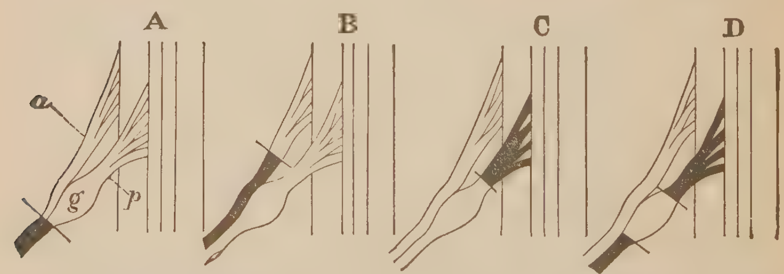


FIG. 200. — DEGENERATION OF SPINAL NERVES AND NERVE-ROOTS AFTER SECTION. *A*, section of nerve trunk beyond the ganglion; *B*, section of ventral root; *C*, section of dorsal root; *D*, excision of ganglion; *a*, ventral root; *p*, dorsal root; *g*, ganglion.

the processes of a neurone are cut off, they will suffer from malnutrition and die. If, for instance, a spinal nerve be cut, all the peripheral part will die, since the fibres composing it have been cut off from their cell-bodies situated in the cord, or in the spinal ganglia. The divided ends of a nerve that has been cut across readily reunite by cicatricial tissue, — that is to say, the connective tissue framework unites, but the cut ends of the fibres

themselves do not unite. On the contrary, the peripheral or severed portion of the nerve begins to degenerate, the medullary sheath breaks up into a mass of fatty molecules and is gradually absorbed, and finally the axone also disappears. In regeneration, the new fibres grow afresh from the axone of the central end of the severed nerve-trunk, and penetrating into the peripheral end of the neurilemma, grow along this as the axone of the new nerve, each axone after a time becoming surrounded with a medullary sheath. Restoration of function in the nerve may not occur for several months, during which time it is presumed the new nerve-fibres are slowly finding their way along the course of those which have been destroyed.

Distribution of the terminal branches of the spinal nerves. — After leaving the spinal canal each spinal nerve divides into two main trunks known as the ventral and dorsal divisions. Each of these contain sensory and motor fibres. The ventral division supplies the extremities and parts of the body in front of the spine. The dorsal division supplies the muscles and skin of the back of the head, neck, and trunk. Each ventral division connects with the sympathetic system by means of fibres which pass from the nerve to the sympathetic system and *vice versa*. Previous to their final distribution in the cervical, sacral, and lumbar regions these nerves form plexuses known as the cervical, sacral, and lumbar plexuses. In passing to the viscera, muscles, skin, etc., these terminal nerves follow the same pathway as the blood-vessels. (See Fig. 197.)

Names of peripheral nerves. — Many of the larger branches given off from the spinal nerves bear the same name as the artery which they accompany, or the part which they supply. Thus the radial nerve passes down the radial side of the forearm, in company with the radial artery; the intercostal nerves pass between the ribs in company with the intercostal arteries. An exception to this are the two sciatic nerves which pass down from the sacral plexus, one on either side of the body near the centre of each buttock, and the back of each thigh, to the popliteal region where each divides into two large branches which supply the leg and foot. Motor branches from these nerves pass to nearly all the muscles of the legs and feet and they receive sensory branches from nearly all parts of the skin of the lower extremities.

Functions of the spinal cord: —

(*a*) **Conduction**, or the conveyance of impulses and sensations between the centres and the periphery.

(*b*) **Reflex action**, *i.e.*, the origination of an impulse or action in response to stimulation from the periphery, without of necessity involving the brain in the act, or even without consciousness of the reflex act, on the part of the individual.

(*c*) **Automatic acts**, *i.e.*, acts set up primarily in the cells of the cord by the cells themselves, and not as a result of stimulation by brain cells (voluntary acts) nor as a result of peripheral stimulation.

(*d*) **Inhibition of reflex acts.** — If every outside stimulation were allowed its full effects in the setting up of reflex acts, the body would be on "the jump" all the time. This overactivity is checked unconsciously by the cells of the spinal cord endowed with this function.

(*e*) **Transference**, *i.e.*, an apparent transferring of impulses from one set of fibres to another.

THE BRAIN

The brain is the largest and most complex mass of nervous tissue in the body. It is contained in the cavity formed by the bones of the cranium, and is covered by three membranes (also named meninges), — the dura mater, pia mater, and arachnoid.

The **dura mater** is a dense membrane of fibrous connective tissue containing a great many blood-vessels. It is arranged in two layers and the layers are attached except in a few places. The external layer is adherent to the bones of the skull, and forms their internal periosteum. The internal layer covers the brain and sends numerous prolongations inward for the support and protection of the different lobes of the brain. These projections also form sinuses that return the blood from the brain, and sheaths for the nerves that pass out of the skull. It may be called the protective membrane.

The **pia mater** is a delicate membrane of connective tissue, containing an exceedingly abundant network of blood and lymph-vessels. It dips down into all the crevices and depressions of the brain, carrying the blood-vessels which go to every part. It may be called the vascular or nutritive membrane.

The **arachnoid** is a delicate serous membrane which is placed between the dura mater and the pia mater. With the exception of the longitudinal fissure, it passes over the various eminences and depressions on the surface of the brain and does not dip down into them like the pia mater. Between the arachnoid and the pia mater is a space called the subarachnoid space in which is a certain amount of cerebro-spinal fluid.

Meningeal spaces and cerebro-spinal fluid. — The meningeal membranes and the spaces filled with fluid form a pad enclosing the brain and cord on all sides. The fluid within the ventricles and surrounding the brain is in free communication with that within the central canal of the cord, and the spaces surrounding the cord. Experimental work indicates that cerebro-spinal fluid is formed in the ventricles from the blood and may be due to a process of active secretion. The stream of liquid starts within the ventricles, passes out through foramina into the subarachnoidal spaces, from which it is in turn absorbed by the veins.

The cerebro-spinal fluid is a thin, watery fluid having a specific gravity of 1.007 to 1.008. It contains traces of proteins and other organic substances. The normal amount is difficult to determine but is usually stated as from 60 to 80 cc. It may be formed very promptly from the blood, and when in excess be absorbed quickly by the blood.

Structure of the brain. — The whole brain appears to consist of a number of isolated masses of gray matter — some large, some small — connected together by a multitude of medullated fibres (white matter) arranged in perplexing intricacy. But a general arrangement may be recognized. The numerous masses of gray matter in the interior of the brain may be looked upon as forming a more or less continuous column, and as forming the **core** of the central nervous system, while around it are built up the great mass of the cerebrum and the smaller mass of the cerebellum. This central core is connected by various bundles of fibres with the spinal cord, besides being, as it were, a continuation of the gray matter in the centre of the cord. It is also connected at its upper end by numberless fibres to the gray matter on the surface of the cerebrum.

Weight of the brain. — With the exception of the whale and the elephant, the human brain is heavier than that of any of the lower

animals. The average weight of the brain in the male is 49.5 ounces avoirdupois (about 1485 gms.); in the female, 44 ounces avoirdupois (about 1320 gms.). It appears that the weight of the brain increases rapidly up to the fifth year and ceases to grow generally in the eighteenth or twentieth year. After the sixtieth year the brain loses weight, at first slowly, later more rapidly.

Divisions of the brain. — The brain is divided into four principal parts: the cerebrum, the cerebellum, the pons Varolii and the medulla oblongata.

The medulla oblongata. — The medulla oblongata, also known as the spinal bulb, is continuous with the spinal cord, which, on passing into the cranial cavity through the foramen magnum, widens into an oblong-shaped mass. It is directed (from above) backward and downward, its ventral surface resting on a groove in the occipital bone and its dorsal surface forming the floor of a cavity between the two halves, or hemispheres, of the cerebellum. It is hollow, and the cavity, called the fourth ventricle, is an expanded continuation of the tiny central canal which runs throughout the whole length of the spinal cord. The gray matter is found in the interior, and the white matter on the exterior; most of the gray matter is found on the floor of the fourth ventricle, and from this gray matter arise most of the cranial nerves. The medulla has a ventral and a dorsal median fissure; at the lower part of the ventral fissure are nerve-fibres which cross from one side to the other or *decussate.*

Functions of the medulla oblongata. — The functions of the medulla are similar to the first three listed under the functions of the cord, *i.e.*, conduction, reflex action, and automatic action.

As all the impressions passing between the brain and spinal cord must be transmitted through the medulla, the function of conduction is a very important one. As previously stated, the medulla contains important vital and reflex centres. The principal ones are: —

(1) The respiratory centres for regulating the function of respiration.

(2) Accelerator centres for the heart.

(3) Vasomotor centre.

Subsidiary centres are also found in the spinal cord. The vasomotor nerves are of two kinds, — vaso-constrictor and vaso-dilator. These nerves control the caliber of the blood-vessels and thus help

to control such important processes as the circulation of the blood, metabolism, and heat regulation. While these nerves are always considered as belonging to the sympathetic system, it should be noted that the centre controlling them is located in the medulla.

(4) Other centres, *e.g.*, the vomiting centre, etc.

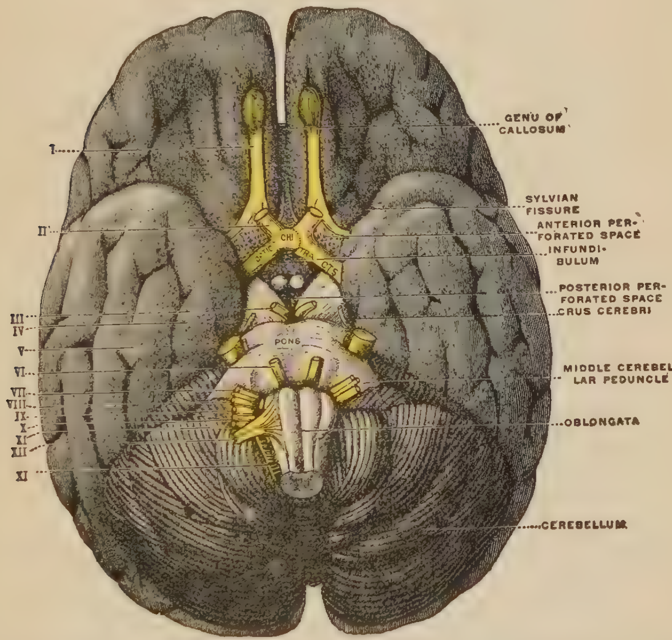


FIG. 201. — UNDER SURFACE OF THE BRAIN, SHOWING THE SUPERFICIAL ORIGINS OF THE CRANIAL NERVES. The roman numerals indicate the nerves. (Gerrish.)

The medulla being the seat of such important centres as those controlling respiration and the heart's action, the student will readily appreciate that, if the medulla be seriously injured, death will result.

Cerebellum. — The cerebellum, or "little brain," occupies the lower and back part of the skull cavity, overhanging the medulla oblongata. It is of a flattened, oblong shape, and measures from three and a half to four inches (8.7 to 10 cm.) transversely, and from two to two and a half inches (5 to 6.3 cm.) from before backward. It is arbitrarily divided into a medial segment called the *vermis* and two lateral lobes or hemispheres; each lobe being subdivided by fissures into smaller portions.

The surface of the cerebellum consists of gray matter and is traversed by numerous curves, or furrows, which vary in depth. The interior consists of white matter.

Peduncles of cerebellum. — The cerebellum is connected with the rest of the cerebro-spinal system by many white nerve fibres grouped in bundles, called the peduncles.

The peduncles are arranged in three pairs. The anterior (superior) peduncles pass forward from the cerebellum to enter into the cerebrum. The posterior (inferior) peduncles pass down to the medulla, where they are known as the *restiform bodies.* The middle pair pass into and make up the larger portion of the pons Varolii, thus serving as a means of intercommunication between the two halves of the cerebellum. Thus it is seen that the cerebellum communicates freely with the entire cerebro-spinal system.

Functions of the cerebellum. — The principal function of the cerebellum seems to be the coördination of ordinary movements and the maintenance of equilibrium.[1] The reason for this belief is that disease or destruction of the cerebellum apparently exerts no malign influence on sensory nerves nor upon the intellect. The motor system is, however, profoundly deranged. Motion itself is not destroyed, but coördination is so interfered with that movements of one part of the body cannot be adapted to other parts.

Pigeons deprived of the cerebellum will fly if thrown from a roof, but the delicacy of the coördination being lost, they turn a series of somersaults in the air and soon fall to the ground.

Pons Varolii. — The pons Varolii, or bridge of Varolius, lies in front of the upper part of the medulla oblongata. It consists of interlaced transverse and longitudinal white nerve-fibres intermixed with gray matter. The transverse fibres are those derived from the middle peduncles of the cerebellum and, as already stated, serve to join its two halves. The longitudinal fibres join the medulla with the cerebrum.

Functions of pons Varolii. — The pons is a bridge of union between the two halves of the cerebellum and a bridge between the medulla and the cerebrum. It is also a place of exit for the fifth, sixth, seventh, and eighth cranial nerves.

[1] A portion of the inner ear is also concerned in maintaining equilibrium.

Cerebrum. — The cerebrum is by far the largest part of the brain. It is egg-shaped, or ovoidal, and fills the whole of the upper portion of the skull. The entire surface, both upper and under, is composed of layers of gray matter, and is called the cortex because, like the bark of a tree, it is on the outside. The bulk of the white matter in the interior of the cerebrum consists of very small fibres running in three principal directions: (1) from above downward, (2) from the front backward, and (3) from side to side. The fibres link the different parts of the brain together, and connect the brain with the spinal cord.

Fissures and convolutions. — In early life the cortex of the cerebrum is comparatively smooth, but as time passes and the

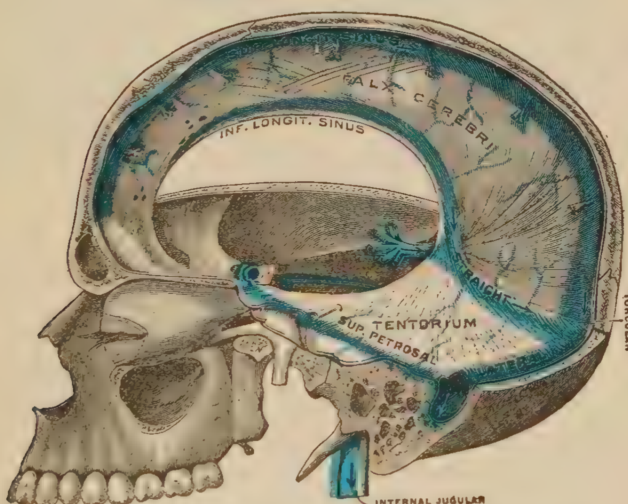


FIG. 202. — FALX CEREBRI AND TENTORIUM, LEFT LATERAL VIEW. (Gerrish.)

brain develops, the surface becomes covered with depressions which vary in depth. The deeper depressions are called *fissures*, the more shallow ones *sulci*, and the ridges between the sulci are called *convolutions*. The fissures and sulci are infoldings of gray matter, consequently the more numerous and deeper they are, the greater is the amount of gray matter. The number and depth of these fissures and sulci is thought to bear a close relation to intellectual power; babies and idiots have few and shallow folds, while the brains of men of intellect are always markedly con-

voluted. There are five important fissures which are always present. They are the following: —

(1) The *Great Longitudinal Fissure,* which extends from the back to the front of the cerebrum, and almost completely divides it into two hemispheres, the two halves, however, being connected in the centre by a broad, transverse band of white fibres called the *corpus callosum.* A process of the dura mater extends down into this fissure and separates the two cerebral hemispheres. It is called the *falx cerebri,* because it is narrow in front, and broader behind, thus resembling a sickle in shape. Blood is returned from the brain in venous channels called sinuses. Two important sinuses are lodged between the layers of the falx cerebri. The superior longitudinal sinus is contained in the upper border, and the inferior longitudinal sinus in the lower border. See Fig. 202.

(2) The *Transverse Fissure,* which is between the cerebrum and the cerebellum. A process of the dura also extends into this fissure, and covers the upper surface of the cerebellum and the under surface of the cerebrum. It is called the *tentorium cerebelli.*

(3) Fissure of Rolando, or central fissure. (4) Fissure of Sylvius. (5) Parieto-occipital fissure.	There is one of each in each hemisphere. For location see Fig. 203.

Lobes of the cerebrum. — The longitudinal fissure divides the cerebrum into two hemispheres, and the transverse fissure divides the cerebrum from the cerebellum. The three remaining fissures divide each hemisphere into five lobes. With one exception these lobes were named from the bones of the cranium under which they lie; hence they are known as: —

(1) Frontal lobe.
(2) Parietal lobe.
(3) Temporal lobe.
(4) Occipital lobe.
(5) Central lobe, or Island of Reil (the exception).

(1) The **frontal** lobe is that portion of the cerebrum lying in front of the fissure of Rolando, and usually consists of four main convolutions.

(2) **Parietal** lobe is bounded in front by the fissure of Rolando, and behind by the parieto-occipital fissure.

(3) **Temporal** lobe lies below the fissure of Sylvius and in front of the occipital lobe.

(4) **Occipital** lobe occupies the posterior extremity of the cerebral hemisphere. When one examines the external surface of the hemisphere, there is no marked separation of the occipital lobe from the parietal and temporal lobes that lie to the front; but

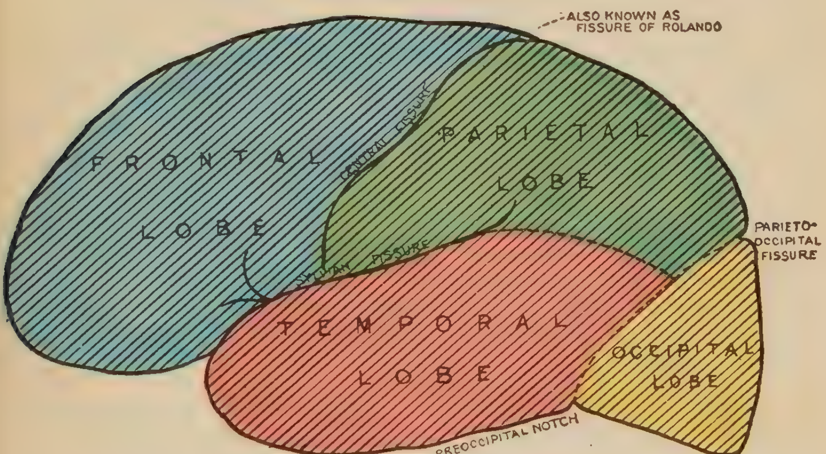


FIG. 203. — THE LOBES OF THE CONVEX SURFACE OF THE HEMISPHERE, LEFT SIDE. (Gerrish.)

when the surface of the longitudinal cleft is examined, the parieto-occipital fissure serves as a boundary anteriorly for the occipital lobe.

(5) **Central** lobe, or Island of Reil, is not seen when the surface of the hemisphere is examined, for it lies within the fissure of Sylvius, and the overlying convolutions of the parietal and frontal lobes must be lifted up before the central lobe comes into view.

Ventricles of the brain. — In describing the spinal cord, reference was made to the **central canal**, being a minute canal running through the centre of the cord throughout its entire length, thus converting the cord into a tube with exceedingly thick walls but very small internal caliber. In the brain proper this same central channel persists, and just as the walls or solid portions of the brain are directly continuous with the wall or solid portion of the spinal cord, so is the cavity of the brain directly con-

tinuous with the central canal of the cord. The cavity in the brain presents some marked differences to that of the cord; while the latter is a straight, fairly uniform canal of very small diameter, the former is at some points very narrow, and at others much widened out so as to form quite good-sized chambers, and these chambers are called the *ventricles* of the brain. These ventricles are filled with cerebro-spinal fluid, just as the canal of the cord is likewise filled with the same fluid.

The ventricles are five in number. The most posterior is the enlargement or expansion of the central canal, occupying the substance of the medulla oblongata, and is called the *fourth ventricle*. Leading forward from the anterior end of the fourth ventricle, the caliber of the canal again narrows to a very small diameter; the canal on reaching the brain substance uniting the two halves of the cerebrum, again expands into a somewhat smaller chamber, called the *third ventricle*. The small canal already mentioned as joining the third and fourth ventricles is known as the *aqueduct of Sylvius*.

Toward the forward end of the third ventricle there are noted two small channels, the *foramina of Monro*, one on either side leading in a direction forward, upward, and outward, each foramen leading into a very large ventricle occupying the centre of its corresponding cerebral hemisphere, called the *lateral ventricle*.

The *fifth ventricle* is very small, lies between the two lateral ventricles, and is not in communication with the other ventricles.

The student will thus see that both the brain and spinal cord are hollow. In some portions, however (as the spinal cord), the interior cavity is so minute and the walls so exceedingly thick that the cavity is a negligible quantity, and the mass can practically be considered as solid; on the other hand, in the case of the ventricles, especially the lateral ventricles, the cavity is large enough to occupy an appreciable space, and may become overdistended with cerebro-spinal fluid in certain conditions of disease.

Functions of the cerebrum. — The nerve centres which govern all our mental activities and the coördination of movements are centred in the cerebrum. These centres are the seat of reason, intelligence, will, memory, and all the higher emotions and feelings.

Localization of brain function. — As the result of numerous experiments on animals, and close observation of individuals suffering from cerebral diseases or wounds, physiologists have been able to localize certain areas in the brain which control motor and sensory activity. They have also been able to gain some knowledge of the areas in the cerebrum which are concerned with the higher mental activities.

Names of areas. — That portion of the cerebrum which governs muscular movement is known as the *motor area*, the portions controlling sensation as the *sensory areas*, and those connected with the higher faculties, such as reason and will, as *association areas.*

Motor areas. — The surface of the brain assigned to the function of motion is the posterior part of the frontal lobe, *i.e.*, the

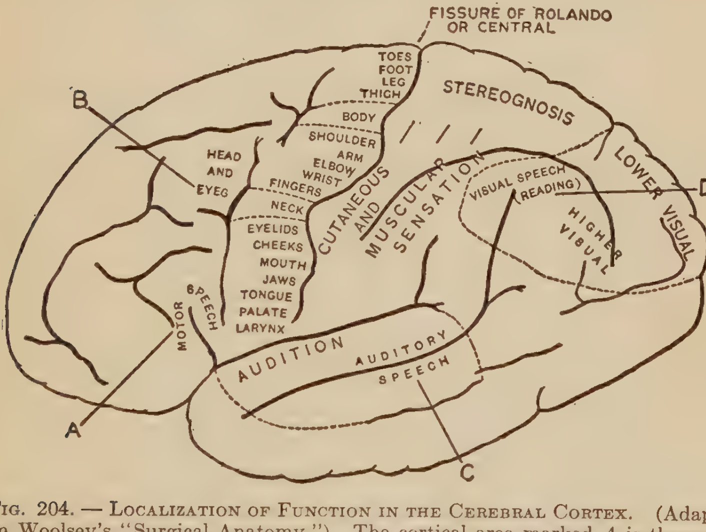


FIG. 204. — LOCALIZATION OF FUNCTION IN THE CEREBRAL CORTEX. (Adapted from Woolsey's "Surgical Anatomy.") The cortical area marked *A* is the motor speech centre, damage to which causes loss of the word-forming power (motor aphasia). Damage to the cortical area marked *B* abolishes the power of writing, a form of sensory aphasia called agraphia. Damage to the centre marked *C* produces word-deafness (sensory aphasia). Damage to the cortical area marked *D* produces word-blindness (sensory aphasia). Stereognosis means the ability to recognize the form of objects by the sense of touch.

gray matter immediately in front of the fissure of Rolando. The movements of various parts of the body are controlled by nerves arising in this area, and the special portions of the area in which the nerves supplying the various parts arise can be studied in Fig. 204.

Decussation of nerves. — The fibres extending from the brain into the cord, and from the cord into the brain, decussate or cross in the medulla. Because of this it follows that the nerves arising in the cortex of the right side govern the movements of the left side of the body, and *vice versa.*

In many cases of paralysis or convulsions, it is possible to locate the exact portion of the brain that is affected, by close observation of the part of the body involved in the loss of function or convulsion.

Sense areas. — The term *sense areas* is used to designate those parts of the brain to which sensation is due, and which control vision, hearing, smell, taste, and to some extent, speech. The visual area is situated in the posterior part of the occipital lobe; the auditory area in the superior part of the temporal lobe; and the olfactory and gustatory areas are in the anterior part of the temporal lobe.

Location of speech areas. — There are four small areas in the cerebral cortex, marked A, B, C, D, in Fig. 204 which are known as the speech centres. They do not develop in both hemispheres. In right-handed persons they become fully developed in the left hemisphere, and in left-handed persons in the right hemisphere. Injury to these centres results in some form of inability to speak,[1] to write,[2] or to understand, spoken[3] or written[4] words. It is customary, therefore, to distinguish two types of aphasia; *i.e.*, motor and sensory. By motor aphasia is meant the condition of those who are unable to speak, although there is no paralysis of the muscles of articulation. By sensory aphasia is meant the condition of those who are unable to understand written, printed, or spoken symbols of words, although the sense of vision and of hearing are unimpaired. These centres are really memory centres and aphasia is due to loss of memory either of words, or the meaning of words seen or heard, or of how to form letters. How these areas control memory is *not* known. The basis of language is a series of memory pictures: (1) of the sound of words; (2) of their appearance; (3) of the effort necessary to enunciate them; and (4) to write their symbols. These memory pictures are closely related to each other by association fibres passing between their centres.

[1] Aphasia. [2] Agraphia. [3] Word-deafness. [4] Word-blindness.

Association areas. — The motor and sense areas previously outlined form, so to speak, small islands which are surrounded on all sides by cerebral tissue in which as yet no definite functions have been localized. These *unknown* regions are designated as association areas and are supposed to be set aside for the mediation of the various mental activities. The different sensory impressions are here moulded into complex perceptions and concepts and are then brought into relation with the motor organs.

In a general way it may be said that the cerebrum is the seat of associations the sum total of which constitutes our psychic life. In the absence of this organ, any animal must cease to be an association or reaction animal and must become a reflex animal. In other words, all its actions are then removed from volition, in fact, from consciousness. All responses that depend upon memory of acquired and inherited experience have been destroyed.

THE CRANIAL NERVES

The cranial nerves consist of twelve pairs. They each have a superficial and a deep origin. The *superficial origin* is the point where they emerge from the under surface of the cerebrum and the medulla, but they can be traced back to various centres in the higher part of the brain, and these centres constitute their *deep origin.*

Classification. — The cranial nerves are of three varieties: (1) sensory nerves, (2) motor nerves, and (3) mixed nerves or those containing both sensory and motor fibres. Many of the cranial nerves arise from several nerve centres, and therefore consist of several bundles of nerve-fibres. After these nerves leave the cranium they split up into branches that are widely distributed.

Numbers and names. — They are named numerically according to the order in which they arise from the brain, and also by names which describe their nature, function, or distribution. The following doggerel may assist the beginner in learning the order of the cranial nerves. Each capital letter denotes a cranial nerve. "On Old Manhattan's Peaked Tops, A Finn And German Picked Some Hops."

(1) The **olfactory** nerve is the special nerve of the sense of smell. Its origin is in the olfactory bulb, and its peripheral fibres are distributed to the upper third of the nasal cavity.

(2) The **optic** nerve is the special nerve of the sense of sight. Its cell-bodies are situated in the retinal coat of the eye.

(3) The **motor oculi** nerve supplies all the muscles of the eye except the superior oblique and the external rectus. It originates in the gray matter of the pons Varolii.

(4) The **pathetic**, or **trochlear**, nerve supplies only the superior oblique muscle of the eye. It arises close to the preceding nerve.

(5) The **trifacial** has two roots, — a dorsal, or sensory, and a ventral, or motor. The fibres from the two roots coalesce into one trunk, and then subdivide into three large branches: (1) the ophthalmic, (2) the superior maxillary, and (3) the inferior maxillary. The ophthalmic branch is the smallest, and is a sensory nerve. It supplies the eyeball, the lacrimal gland, the mucous lining of the eye and nose, and the skin and muscles of the eyebrow, forehead, and nose. The superior maxillary, the second division of the fifth, is also a sensory nerve, and supplies the skin of the temple and cheek, the upper teeth, and the mucous lining of the mouth and pharynx. The inferior maxillary is the largest of the three divisions of the fifth, and is both a sensory and a motor nerve. It sends branches to the temple and the external ear; to the teeth and lower jaw; to the muscles of mastication; it also supplies the tongue with the special nerve (lingual) of the sense of taste. The cell-bodies of the motor fibres are situated in the pons; while those of the sensory fibres, as in the case of the spinal nerves, are situated in a ganglion. This ganglion is called the Gasserian ganglion.

(6) The **abducens** nerve supplies the external rectus muscle of the eye.

(7) The **facial** nerve is the motor nerve of all the muscles of expression in the face; it also supplies the neck and ear. Its cells of origin, like those of the abducens nerve, are situated in the medulla.

(8) The **auditory** nerve is the special nerve of the sense of hearing. It arises from cells which compose the organ of Corti in the internal ear, to which its fibres are exclusively distributed.

(9) The **glossopharyngeal** nerve is distributed, as its name indicates, to the tongue and pharynx, being the special nerve of taste to part of the tongue, the nerve of sensation to the mucous membrane of the pharynx, and of motion to the pharyngeal muscles.

(10) The **pneumogastric** or **vagus** nerve has a more extensive distribution than any of the other cranial nerves, passing through the neck and thorax to the upper part of the abdomen. It contains both motor and sensory fibres. It supplies the organs of voice and respiration with motor and sensory filaments; and the pharynx, œsophagus, stomach, and heart with motor fibres (cardiac inhibitory).

(11) The **spinal-accessory** nerve consists of two parts: one, the spinal portion, and the other, the accessory portion to the tenth nerve. It is a motor nerve supplying certain muscles of the neck. It differs from the other cranial nerves in arising from the spinal cord, but it leaves the skull by the same aperture as the pneumogastric and glossopharyngeal.

(12) The **hypoglossal** nerve is the motor nerve of the tongue.

Functions of the nervous system. — The various systems of the body function together harmoniously and in such a way that the individual responds properly to his environment. The interpretation of environmental conditions and the adaptive responses of the organism as a whole to these conditions, is carried out by the nervous system. It enables us to think and to will, to recognize our surroundings and to accommodate ourselves to them; to move, to talk, to hear, to see; and it guarantees equilibrium and muscular coördination. In short, it makes possible all the higher functions of human life.

SUMMARY

Neurone Concept	The nervous system may be reduced to a simple unit called a neurone. The neurone may be regarded as the building stone of the nervous system.	
Reflex Concept	Nervous activity of all kinds may be reduced to reflex action. The reflex circuit forms the functional basis of all nervous activity.	
Types of Reflex Circuits	1. Consists of two neurones	Receptor or sensory. Effector or motor.
	2. Consists of three neurones	Sensory or receptor. Central or correlation. Motor or effector.
	3. Consists of complexes of above.	

- **Synapse**
  - Interlacing of the fine branches of the axone of one neurone, with the branches of a dendrite of another neurone. *Not* an anatomical continuation. Nerve-impulses are able to bridge the microscopic gap.
- **Reaction Circuit**
  - When cells in the volitional centres in the cerebrum enter into the reflex circuit, it is spoken of as a reaction circuit.
- **Classification of Reflexes**
  - Simple.
  - Complex.
  - Spreading.
  - Tonic or continuous.
  - Clonic or periodic.
  - Association or perception.
- **Nature and Speed of Nerve Impulses**
  - Nature not positively known.
  - Presumably a physical molecular vibration.
  - Identical in character, vary only in intensity.
  - Speed is about 100 to 140 ft. per second.
- **Nerve-endings**
  - Not all affected by the same stimuli.
  - Special end organs to mediate each sense.
- **Grouping of Neurones**
  - **Gray matter**
    - Consists of
      - Cell-bodies.
      - Dendrites.
      - Commencement of axones.
    - Found in
      - Brain.
      - Spinal cord.
      - Ganglia.
  - **White matter**
    - Consists of medullated nerves.
    - Found in
      - Brain.
      - Spinal cord.
      - Ganglia.
      - Nerve-trunks.
- **Nervous System**
  - Sympathetic System
    1. Vertebral ganglia.
    2. Collateral ganglia.
    3. Terminal ganglia and plexuses.
    4. Sympathetic ganglia in the brain and cord.
    5. Sympathetic nerves.
  - Central Nervous System
    1. Spinal cord and spinal nerves.
    2. Brain
       - Medulla Oblongata.
       - Cerebellum.
       - Pons Varolii.
       - Cerebrum.
    3. Cranial nerves.

- **Sympathetic System**
  - **Vertebral Ganglia**
    - Chain of ganglia situated on either side of spinal column.
    - **Grouped as**
      - Cervical . . . . . . 3 prs.
      - Thoracic . . . . . . 10–12 prs.
      - Lumbar . . . . . . 4 prs.
      - Sacral . . . . . . 4–5 prs.
    - **Connected**
      1. With each other by ganglia cords.
      2. With spinal nerves by rami communicantes.
      3. With viscera
         - *a.* Pass directly to viscera.
         - *b.* Converge to form
           - Great splanchnic.
           - Small splanchnic.
           - Least splanchnic.
         - *c.* Join collaterals and plexuses.
         - *d.* Join spinal nerves.
  - **Collateral Ganglia**
    - Located principally in thoracic and abdominal cavities.
    - **Connected**
      - With spinal nerves.
      - With vertebral ganglia.
      - With viscera.
    - **Form**
      - Cardiac plexus.
      - Solar plexus.
      - Hypogastric or pelvic plexus.
  - **Terminal Ganglia**
    - Located on walls of organs themselves.
    - Connected with collateral ganglia.
  - **Sympathetic Ganglia** are found in the medulla, spinal cord, and in connection with some of the cranial nerves.
  - **Sympathetic Nerves.**

- **Distribution of Sympathetic Nerves**
  - To the heart.
  - To the involuntary muscles of the blood-vessels, lymphatics, and viscera.
  - To the secretory glands.
  - To some of the special senses.

- **Function and interdependence of Sympathetic System**
  - Regulatory control over visceral activities.
  - The term autonomic applied to functional activities of sympathetic system.
  - Sympathetic and central nervous system are interdependent both anatomically and physiologically.

- **Spinal Cord**
  - Located in spinal canal.
  - Extends from foramen magnum to second lumbar vertebra.
  - Varies in length from 16 to 20 inches.
  - Consists of
    - Gray matter in form of H.
    - White matter in funiculi
      - Anterior.
      - Posterior.
      - Lateral.
  - **Fissures**
    - Ventral divides front portion in lateral halves.
    - Dorsal divides back portion in lateral halves.
  - **Isthmus** — connects lateral halves.
  - **Canal** — centre of isthmus.
  - **Membranes**
    - **Pia mater** — inner membrane, closely invests spinal cord.
    - Subarachnoid space.
    - **Arachnoid** — middle membrane.
    - Subdural space.
    - **Dura mater** — outer membrane.
    - Epidural space.
  - **Functions**
    1. Conduction.
    2. Reflex action.
    3. Automatism.
    4. Inhibition.
    5. Transference.

- **Spinal Nerves**
  - **Number**

Cervical	8 pairs.
Thoracic	12 pairs.
Lumbar	5 pairs.
Sacral	5 pairs.
Coccygeal	1 pair.
	31 pairs.

  - **Variety**
    - Medullated.
    - Mixed
      - Sensory.
      - Motor.
  - **Origin** — two roots
    - Ventral in gray matter of cord.
    - Dorsal in spinal ganglia.
  - **Distribution** — two trunks
    - Ventral, supplies extremities, and parts of body in front of spine.
    - Dorsal, supplies muscles and skin of back of head, neck, and trunk.

- **Brain**
  - Located in cranial cavity.
  - Covered by meninges — same as spinal cord.
  - **Divisions**
    - **Medulla Oblongata.**
    - **Cerebellum.**
    - **Pons Varolii.**
    - **Cerebrum.**

- **Cerebro-spinal Fluid**
  - Found in meningeal spaces of brain and cord, central canal of cord, and ventricles of the brain.
  - Thin, watery fluid formed from blood.
  - Specific gravity 1.007 to 1.008.
  - Amount is about 60 to 80 cc.

- **Medulla Oblongata**
  - **Description**
    - Oblong-shaped mass, upward continuation of cord.
    - Gray matter in interior.
    - White matter on exterior.
  - **Function**
    - Conduction.
    - Reflex action.
    - Automatism.
    - Respiratory centre.
    - Accelerator centre for heart.
    - Vasomotor centres and others.

- **Cerebellum**
  - **Description**
    - Flat oblong-shaped mass, overhangs medulla.
    - 3–4½ in. transversely.
    - 2–2½ in. from before backward.
    - Gray matter on exterior.
    - White matter in interior.
  - **Function**
    - Coördination.
    - Maintenance of equilibrium.

- **Pons Varolii**
  - A bridge of nerve-fibres connecting two halves of cerebellum and also medulla with cerebrum.

- **Cerebrum**
  - **Description**
    - Egg-shaped or ovoidal.
    - Fills upper portion of skull.
    - Gray matter on outside
      - Fissures.
      - Sulci.
      - Convolutions.
    - White matter on inside.
    - **Fissures**
      - Great longitudinal fissure.
      - Transverse fissure.
      - Rolandic.
      - Sylvian.
      - Parieto-occipital.
    - **Lobes**
      - Frontal.
      - Parietal.
      - Occipital.
      - Temporal.
      - Central, or Island of Reil.
    - **Ventricles**
      - Fourth ventricle.
      - Third ventricle.
      - Lateral ventricles (two).
      - Fifth ventricle.

Cerebrum
- **Function**
  - Governs all our mental activities
    - Reason.
    - Intelligence.
    - Will.
    - Memory.
    - Higher emotions.
  - Movement and coördination of same.

Names of Areas
- **Motor area** — in front of Fissure of Rolando.
- **Sense areas**
  - Visual — occipital lobe.
  - Auditory — superior part of the temporal lobe.
  - Olfactory, Gustatory — anterior part of temporal lobe.
- **Association areas** — cerebral tissue surrounding motor and sense areas, in which as yet no definite functions have been localized.

Cranial Nerves

I. Olfactory.
II. Optic.
III. Motor oculi.
IV. Pathetic.
V. Trifacial.
VI. Abducens.
VII. Facial.
VIII. Auditory.
IX. Glossopharyngeal.
X. Pneumogastric.
XI. Spinal accessory.
XII. Hypoglossal.

Functions of the Nervous System
- Interpretation of environmental conditions and adaptive responses of the organism as a whole; makes possible all the higher functions of human life.

CHAPTER XX

INTERNAL AND EXTERNAL SENSES: TASTE, SMELL, HEARING, AND SIGHT

THE sensory nerves which we have discussed in the previous chapter have their peripheral endings in receptors or sensory end organs. These receptors receive stimuli, transform these stimuli to nerve-impulses and pass them on to the nerves which carry them to centres in the central nervous system for interpretation or for linkage with motor nerves.

Sense-organ. — A typical sense-organ or sensory unit consists of (1) a peripheral end organ or receptor which in most cases is constructed so as to be responsive only to a special form of stimulus, (2) connecting neurones whose only function is to conduct the nerve-impulses originating in the end organ, and (3) a centre in the nervous system which interprets and determines the quality of the sensation. In this connection physiologists use the phrase *specific nerve energy* to designate the fact that each sense-organ arouses its own specific quality of sensation, and no other. For example, the specific energy of the optic apparatus is visual sensation, and of the auditory apparatus is sound sensation. The view generally adopted is that this specificity is not due to the end organs or conducting nerves, but to the centre in the brain.

Definition of sensation. — Sensation is defined as perception through the sense-organs, and is the result of stimulation of these organs. The sensitiveness of the numerous receptors to stimulation varies; some respond to a very mild stimulus, *e.g.*, in some parts of the body the slightest pressure will arouse a sensation while a similar degree of pressure in another part may fail to produce any sensation at all. The minimal stimulus necessary to arouse a sensation in any receptor is described as the *threshold* stimulus for that organ.

Where sensations are interpreted. — Sensations are felt and interpreted in the brain. Our habit of projecting sensations to the part that is stimulated, tends to obscure this fact. In reality we see and hear with our brains, because the eye and ear serve only as end organs to receive the stimulus which must be carried to the brain and interpreted before we do see or hear.

CLASSIFICATION OF SENSATIONS

Sensations were formerly classified into two groups, *i.e.*, special and common. The special senses were sight, hearing, touch, taste, and smell. All other sensations were grouped as common. A more recent classification is dependent on the part of the body to which the sensation is projected, and the two groups are named: (1) internal or interior senses, and (2) external or exterior senses. These classifications have much in common, but differ slightly.

Internal or interior senses. — The internal senses are those in which the sensations are projected to the interior of the body. It is by means of these senses that we acquire a knowledge of the condition of our body. Among the interior senses we must include pain, the sensations from the semicircular canals and vestibule of the internal ear, hunger, thirst, sexual sense, muscle sense, fatigue, and various obscure sensations which proceed from the viscera and give us the feeling of well-being or the reverse, also the desire for defecation or urination.

External or exterior senses. — The external senses are those in which the sensations are projected to the exterior of the body. They form the means by which we become acquainted with the outside world. They include pressure and temperature sense, (heat and cold), taste, smell, hearing, and sight. Even this classification is not absolutely distinctive, as some sensations may be projected either to the interior or exterior of the body. Temperature and pain are examples of this class.

Cutaneous sensation. — Modern physiology teaches that the sensory nerves of the skin mediate four different qualities of sensation, *i.e.*, pressure, cold, heat, and pain. As a result the surface of the skin is a mosaic of tiny sensory spots separated by relatively wide intervals. Each spot coincides with the location of some special end organ and serves a specific sense. These various

spots are placed either singly or in clusters. In some locations one variety predominates, in others another. It is a matter of common knowledge that the sensitiveness of these varieties of cutaneous sensation differs in different parts of the body, *e.g.*, the tip of the finger is more sensitive to pressure or contact than to alterations of temperature. The hot and cold spots and

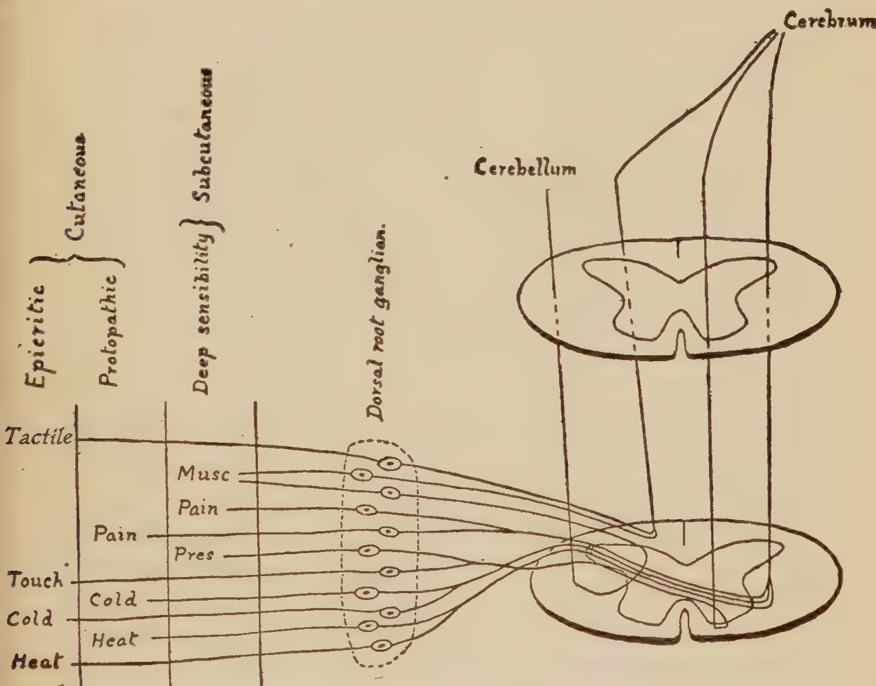


FIG. 205. — DIAGRAM OF COURSE OF CUTANEOUS FIBRES ON REACHING THE CORD. (Dawson.)

the pressure points can be located by passing a metallic point slowly over the skin. At certain points a feeling of contact or pressure will be experienced, and at other points a feeling of cold or heat, depending on whether the temperature of the instrument is higher or lower than that of the skin.

Classification of cutaneous sensations. — It has recently been suggested that the cutaneous senses be classified on the basis of the loss of sensation after division of the cutaneous nerves and the subsequent, gradual, and separate return of these sensations, after suture of the divided ends. It has been found that the skin

is supplied with two sets of nerve-fibres which regenerate at different times and these are named respectively protopathic and epicritic. The *protopathic* group comprises three qualities of sensation, *i.e.*, (1) pain, (2) heat above 37° C., and (3) cold below 26° C. This system conveys sensations of pain and of extreme changes of temperature but the sensibility is low and the localization poor. It is found in the viscera and from a functional standpoint may be considered as a defensive agency toward pathologic changes. The *epicritic* group contains separate fibres for heat, cold, light pressures, and tactile discriminations which give us sensations of (1) light touch and (2) small differences of temperature between 26° C. and 37° C., *i.e.*, the range of temperature to which the temperature nerves of the protopathic system are insensitive. This group constitutes the special characteristic of the skin area and is not found in other organs.

In addition to the protopathic fibres the deeper tissues are supplied with fibres which give us a sense of pressure, and in the case of the muscles and joints, with fibres which give us a knowledge of the position of the movable parts of the body. The paths which these various fibres take in their journey through the central nervous system may be studied in Fig. 205.

Pain. — It is probable that pain is the most widely distributed sense in the body. It is present throughout the skin and may be aroused by stimulation of the sensory nerves in the various viscera and membranes of the body. Our knowledge of the physiological properties of the end organs and nerves mediating this sense is limited to the skin. There is much evidence to support the view that for cutaneous pain there exists a special set of fibres which have a specific energy for pain. The pain points in the skin are more numerous than the pressure points and their sensitiveness varies, *e.g.*, the threshold stimulus for the cornea is lower than in the case of the finger tips.

Referred pains. — Normally we are able to localize pain arising in the skin, accurately. On the contrary, pain arising in the viscera is often located very inaccurately and referred to an entirely wrong place. The explanation of this misreference is that the pain is referred to, or appears to come from, the skin region that is supplied with sensory fibres from the same spinal segment that supplies the organ in question, and is due to a diffusion in the nerve centres.

Muscle sense. — The end organs of the muscle sense are situated in the tendons and between the fibres of the muscles. From these end organs afferent fibres carry impulses to centres in the brain, which send out impulses along efferent fibres to the muscles. There is thus a circle of nerves between the brain and the muscles, one nerve giving the sense of the condition of the muscle to the brain, and another carrying the impulse from the brain to the muscle. This gives us a certain consciousness of the condition of our muscles at all times, and enables us to coördinate the contractions of harmonious groups in order to produce voluntary movements.

Hunger. — Hunger occurs normally at a certain time after meals and is usually projected to the region of the stomach. It is presumably due to contractions of the empty stomach, which stimulate the nerves distributed to the mucous membrane. In abnormal conditions, *e.g.*, severe illness and extreme fatigue these periodic contractions may be weaker than usual, or may not occur at all.

Thirst. — This sensation is projected to the pharynx. We know very little about the nervous mechanism involved, but it is thought that when the water content in the tissues falls below a certain amount, the sensory nerve-fibres in the pharynx are stimulated and produce the sensation of thirst.

TASTE

Necessary conditions. — Aside from the conditions which are always necessary for sense-perception, — viz. proper organs for receiving, communicating, and perceiving the sensory impulse, — there must be present a sapid substance which must be in solution. The solution in the case of dry substances is effected by saliva. It is also necessary that the surface of the organs of taste shall be moist. The substances which excite the special sensation of *taste*, act by producing a change in the terminal filaments of the fifth, seventh, and ninth nerves and this change furnishes the required stimulant.

Organs of taste. — The special organs of the sense of taste are end organs of nerve filaments which are derived from the trifacial, facial, and glossopharyngeal nerves. These end organs are called *taste buds* and are situated chiefly on the surface of the tongue,

though some are scattered over the soft palate, fauces, epiglottis, and even the vocal cords.

The tongue. — The tongue is a freely movable muscular organ consisting of two distinct halves united in the centre. The base or root of the tongue is directed backward and is attached to the hyoid bone by numerous muscles. It is connected with the epiglottis by three folds of mucous membrane, and with the soft palate by means of the anterior pillars of the fauces.

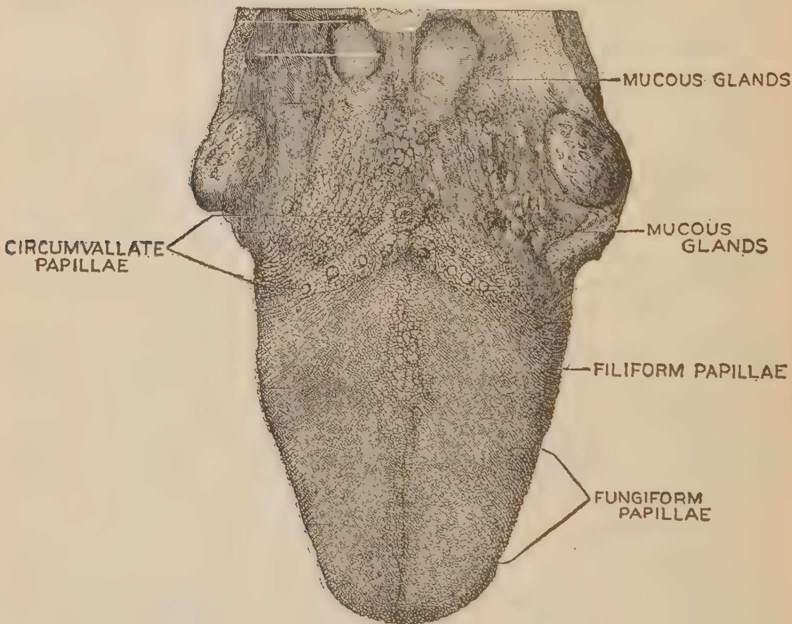


FIG. 206. — THE UPPER SURFACE OF THE TONGUE. (Sappey.)

Papillæ of the tongue. — The tongue is covered and lined with mucous membrane. The mucous membrane on the under surface is similar to that lining the rest of the mouth, but the mucous membrane on the upper surface is studded with papillæ which project as minute prominences and give the tongue its characteristic rough appearance. Of these papillæ there are three varieties: —

(1) Circumvallate (walled in) papillæ are the largest, are circular in shape, and form a V-shaped row near the root of the tongue, with the open angle of the V turned toward the lips. They serve to secrete mucus and contain *taste buds* in which the filaments of the glossopharyngeal nerve terminate.

(2) Fungiform papillæ are the next in size, and are so named because they resemble fungi in shape. They are found principally on the tip and sides of the tongue. Each fungiform papillæ contains a loop of capillaries and a nerve-fibre derived from the glossopharyngeal nerve.

(3) Filiform papillæ are the smallest and most numerous. They are found all over the tongue, except at the root, and bear on their free surface delicate hair-like processes which seem to be specially connected with the sense of touch, which is very highly developed on the tip of the tongue.

Nerve supply of the tongue. — The nerve-fibres which terminate in the taste buds are: (1) filaments of the lingual nerve, which is a branch of the fifth or trifacial, (2) filaments of the chorda tympani, a branch of the seventh or facial, and (3) filaments of the ninth or glossopharyngeal nerve.[1] The twelfth or hypoglossal nerve is distributed to the tongue, but is a motor nerve and is not concerned in the sense of taste or touch.

Other sensations in the tongue. — The sense of touch is very highly developed here, and with it the sense of temperature, pain, etc. Upon these tactile and muscular senses to a great extent depend the accuracy of the tongue in many of its important uses — speech, mastication, deglutition, sucking.

We often confound taste with smell. Substances which have a strong odor, such as onions, are smelled as we hold them in our mouths; and if our sense of smell is temporarily suspended, as it sometimes is by a bad cold in the head, we may eat garlic and onions and not taste them. Hence the practice of holding the nose when we wish to swallow a nauseous dose.

SMELL

Necessary conditions. — The first essentials are a special nerve and nerve-centre, the changes in whose condition are perceived as sensations of odor. No other nerve structure is capable of such sensations, even when acted on by the same cause. The special organs for this sense must be in their normal condition, and a stimulus (odor) must be present to excite them.

Odors are caused either by minute particles of solid matter or

[1] This is the generally accepted view, but other statements may be found in the various text-books.

by gases which are in the atmosphere, and they must be capable of solution in the mucus of the *pituitary*[1] membrane. Odorous particles in the air, passing through the lower, wider air passages, pass by diffusion into the higher, narrower, nasal chambers, and falling on the membrane which is provided with olfactory nerve-endings, produce sensory impulses which, ascending to the brain, give rise to the sensation of smell.

If we wish to smell anything particularly well, we sniff the air up into the higher nasal chambers, and thus bring the odorous particles more closely into contact with the olfactory nerves.

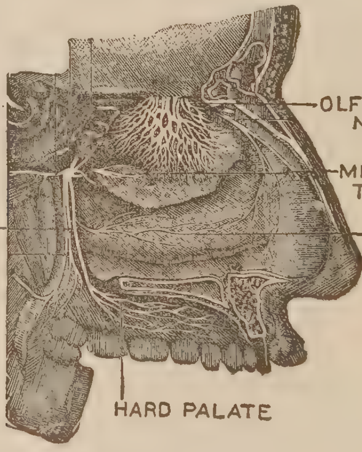


FIG. 207. — VERTICAL LONGITUDINAL SECTION OF NASAL CAVITY.

Each substance we smell causes its own particular sensation, and we are not only able to recognize a multitude of distinct odors, but also to distinguish individual odors in a mixed smell. The sensation takes some time to develop, after the contact of the odorous stimulus, and may last a long time. When the stimulus is repeated, the sensation very soon dies out, the sensory terminal organs quickly becoming exhausted.[2]

Olfactory nerves. — The olfactory nerves are the special nerves of the sense of smell, and are spread out in a fine network over

[1] This name is given to the membrane that lines the nasal passages.

[2] This accounts for the fact that one may easily become accustomed to foul odors, and is of special importance to nurses. Foul odors are quickly noticed by any one coming into a sick room from out of doors, but a nurse who is in the sick room constantly may become accustomed to such odors. Hence the importance of acting on the first sensation of a disagreeable odor.

the surface of the superior turbinated processes of the ethmoid bone and on the upper third of the septum. The nerves end in special organs known as olfactory cells, which lie under the epithelium, but send prolongations between the mucous cells to the surface. The central portions of the olfactory cells are prolonged as nerve-fibres into a mass of gray matter, called the *olfactory bulb,* which rests upon the cribriform plate of the ethmoid bone.

The nerves which ramify over the lower part of the lining membrane of the nasal cavity are branches of the fifth or trigeminal nerve. These nerves furnish the tactile sense and enable us to perceive, by the nose, the sensations of cold, heat, tickling, pain, and tension or pressure. It is this nerve which is affected by strong irritants, such as ammonia or pepper.

HEARING

The auditory apparatus consists of: (1) the external ear; (2) the middle ear; (3) the internal ear; and (4) the auditory nerve.

External ear. — The external ear consists of an expanded portion named **pinna**, or **auricle**, and the **auditory canal**, or **meatus.**

The **auricle**, except the lower portion, consists of a framework of cartilage, containing some fatty tissue and a few muscles. In the lower portion, which is called the lobe, the cartilage is replaced by connective tissue. The auricle is covered with skin, and joined to the surrounding parts by ligaments and a few muscles. It is very irregular in shape, and appears to be an unnecessary appendage to the organ of hearing, except that the central depression, the concha, serves to some extent to collect sound-waves, and to conduct them into the auditory canal.

The **auditory canal** is a tubular passage, about an inch (2.5 cm.) in length, leading from the concha to the drum-membrane. The exterior portion of the wall of the auditory canal consists of cartilage, which is continuous with that of the auricle; the posterior portion is hollowed out of the temporal bone. This canal is slightly curved upon itself so as to be higher in the middle than at either end, and its direction is forward and inward. Lifting the auricle upward and backward tends to straighten the canal; except in the case of children it is best straightened by drawing the auricle downward and backward. It is lined by a prolongation of the skin, which in the outer half of the canal is very thick and not at

all sensitive, and in the inner half is thin and highly sensitive. Near the orifice the skin is furnished with a few hairs, and farther inward with modified sweat-glands, the ceruminous glands, which secrete a yellow, pasty substance resembling wax. This wax is thought to be offensive to insects, and consequently a defence against their intrusion.

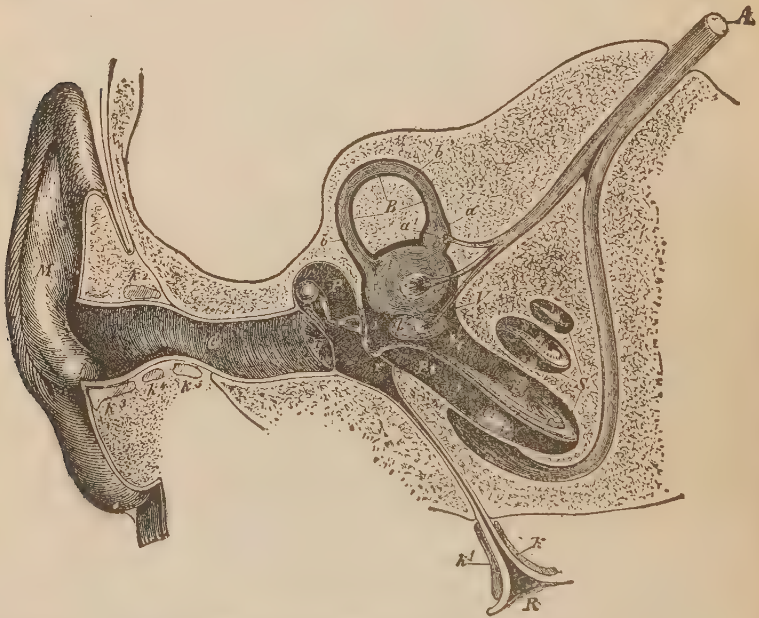


FIG. 208. — SEMI-DIAGRAMMATIC SECTION THROUGH THE RIGHT EAR. *M*, concha; *G*, the external auditory canal; *T*, tympanic, or drum-membrane; *P*, tympanum, or middle ear; *o*, oval window; *r*, round window. Extending from *T* to *o* is seen the chain of the tympanic bones; *R*, Eustachian tube; *V*, *B*, *S*, bony labyrinth; *V*, vestibule; *B*, semicircular canal; *S*, cochlea; *b*, *l*, *v*, membranous labyrinth in semicircular canal and in vestibule. *A*, auditory nerve dividing into branches for vestibule, semicircular canal, and cochlea.

Middle ear. — The middle ear, or tympanum, is a small, irregular bony cavity, situated in the petrous portion of the temporal bone, and lined with mucous membrane. It is separated from the external auditory canal by the drum-membrane (*membrana tympani*), and from the internal ear by a very thin, bony wall in which there are two small openings covered with membrane — the oval window, or *fenestra ovalis*, and the round window, or *fenestra rotunda*. The cavity of the middle ear is so small that probably five or six drops of water would completely fill it.

It communicates below with the pharynx by the small passage called the Eustachian tube.[1]

The function of the tube is to ventilate this cavity and keep the atmospheric pressure equal on each side of the drum-membrane. The middle ear also communicates with a number of bony cavities in the mastoid portion of the temporal bone. These cavities, called mastoid cells, are lined with mucous membrane, which is continuous with that covering the cavity of the tympanum.

Membrana tympani (membrane of the drum). — It is a tough, fibrous membrane set in the bony opening of the external audi-

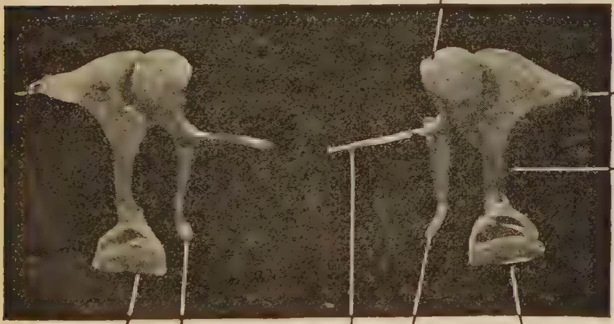


FIG. 209. — OSSICLES OF THE TYMPANUM, × 4. (Flint.)

tory canal. The degree of tension of the membrane is regulated by the tensor tympani muscle. This muscle is lodged in a bony canal that is above and parallel with the Eustachian tube.

Ossicles. — Stretching across the tympanic cavity is a chain of tiny, movable bones, three in number, and named from their shape the **malleus**, or hammer, the **incus**, or anvil, and the **stapes**, or stirrup. The handle of the hammer is attached to the drum-membrane, and the opposite end or head of the hammer is attached to the base of the anvil. The long process of the anvil is attached to the stapes, and the footpiece of the stapes is attached to the fibrous membrane that is stretched across the oval window.

[1] This direct connection between the ear and the pharynx is one of the important reasons for the frequent cleansing of the mouth necessary in infectious diseases. The Eustachian tube forms a passageway for germs to travel from the mouth to the middle ear and there cause various infections.

These little bones are held in position, attached to the drum-membrane, to each other, and to the membrane of the oval window by minute ligaments and muscles. They are set in motion with every movement of the drum-membrane. Vibrations of the membrane are communicated to the hammer, taken up by the anvil, and transmitted to the stirrup, which rocks in the fenestra ovalis, and is therefore capable of transmitting to the fluid in the cavity of the labyrinth the impulses which it receives.

Internal ear. — The internal ear, or labyrinth, receives the ultimate terminations of the auditory nerve, and is, therefore, the essential part of the organ of hearing. It consists of a *bony labyrinth,* which is composed of a series of peculiarly shaped cavities, hollowed out of the petrous portion of the temporal bone, and named from their shape: —

(*a*) The vestibule.
(*b*) The semicircular canals.
(*c*) The cochlea (snail-shell).

Within the bony labyrinth is a *membranous labyrinth,* having the same general form as the cavities in which it is contained though considerably smaller, being separated from the bony walls by a quantity of fluid called the perilymph. It does not float loosely in this liquid because in some places it is attached to the bone by bands of fibrous tissue. The cavity within the membrane is filled with a fluid called *endolymph.*

The **vestibule** is the central cavity situated between the cochlea in front and the semicircular canals behind. It communicates with the middle ear by means of the oval window in its outer wall. The vestibular membrane does not conform to the shape of the bony cavity but consists of two small sacs, called respectively the *saccule* and the *utricle.* The saccule is in front and nearer the cochlea, and the utricle is back and nearer the semicircular canals. These sacs are connected by a tube called the endolymph duct, which is shaped like a Y. The walls of these sacs contain numerous columnar cells provided with stiff hairs which project into the endolymph. These cells are in relation with fibres of the vestibular branch of the auditory nerve and serve as end organs. Among these hair-cells rest several small crystals of calcium carbonate which are called *otoliths.*

The **cochlea** opens from the front end of the vestibule and saccule. It resembles a snail-shell and consists of a spiral tube of two and one-half turns around a central pillar called the *modiolus.*

Projecting from the modiolus is a thin lamina or plate of bone. At its outer margin this lamina connects with a membrane which extends to the outer wall of the cochlea. This lamina and membrane divide the spiral canal into two passages or scalæ. The lower portion of this membrane is called the *basilar membrane*

FIG. 210. — THE LEFT BONY LABYRINTH OF A NEW-BORN CHILD, FORWARD AND OUTWARD VIEW, × 4.

1, the wide canal, the beginning of the spiral canal of the cochlea; 2, the fenestra rotunda; 3, the second turn of the cochlea; 4, the final half-turn of the cochlea; 5, the border of the bony wall of the vestibule, situated between the cochlea and the semicircular canals; 6, the superior, or sagittal semicircular canal; 7, the portion of the semicircular canal bent outward; 8, the posterior, or transverse semicircular canal; 9, the portion of the posterior connected with the superior semicircular canal; 10, point of junction of the superior and the posterior semicircular canals; 11, the ampulla ossea externa; 12, the horizontal, or external semicircular canal. (Flint.)

and consists of a network of fibres which forms the foundation for thousands of cells which serve as the end organs of the auditory nerve. These end organs constitute a structure that is known as the *organ of Corti.* They receive nerve-fibres which arise in the ganglia contained in the cavity of the modiolus. Both the modiolus and lamina are pierced by numerous openings for the passage of these nerves.

The **semicircular canals** are three bony canals lying above and behind the vestibule, and communicating with it by five openings, in one of which two tubes join. They are known as the *posterior,*

vertical, and *horizontal* canals, and their position is such that each one is at right angles to the other two. One end of each tube is enlarged and forms what is known as the ampulla. The membrane of the ampulla is covered with cells that are similar to those found in the utricle and saccule. These hair-cells serve as end organs for the vestibular branch of the auditory nerve.

The auditory nerve. — The eighth or auditory nerve is a sensory nerve and contains two distinct sets of fibres, which differ in their function, origin, and destination. One set of fibres is known as the cochlear division and the other as the vestibular.

The fibres of the **cochlear nerve** arise from bipolar cells that are situated in the modiolus of the cochlea. One axone from each cell passes through the foramina of the modiolus or lamina, and terminates in and around the cells that constitute the organ of Corti. The other axone passes through the internal auditory meatus to a portion of the brain, called the cochlear root of the auditory nerve. This root is located at the lower edge of the pons Varolii. The nerve-fibres which pass from the ear to the pons or from the pons to the ear are not continuous strands, as there are several relays of ganglia in which the axones of one cell interlock with the dendrites of another cell.

The fibres of the **vestibular nerve** have their origin in the gray matter of the pons Varolii. Some of these fibres extend to the cerebellum and to motor centres of the spinal nerves. Other fibres extend to the vestibule and are distributed around the hair-cells of the saccule, utricle, and the ampulla of the semicircular canals.

Physiology of hearing. — All bodies which produce sound are in a state of vibration, and communicate their vibrations to the air with which they are in contact.

When these air-waves, set in motion by sonorous bodies, enter the external auditory canal, they set the drum-membrane vibrating; stretched membranes taking up vibrations from the air with great readiness. These vibrations are communicated to the chain of tiny bones stretched across the middle ear, and their oscillations cause the membrane leading into the internal ear to be alternatively pushed in and drawn out; the vibrations are in this way transmitted to the perilymph. The movements of the perilymph are transmitted to the basilar membrane, and set some of

the strings in motion. In some unknown way these movements are transmitted to the hair-cells and through them to the nerve-fibres at their base. By means of the nerve-fibres the stimulus is conveyed to the brain and interpreted there, so that it is with the brain we hear.

The sense of equilibrium. — Among the various means (such as sight, touch, and muscular sense) whereby we are enabled to maintain our equilibrium, coördinate our movements, and become aware of our position in space, one of the most important is the action of the vestibule and semicircular canals. Though these structures are found in the inner ear and communicate with the cochlea, it is now thought that they are not connected with the sense of hearing. Just how they perform their function is not known, but it is thought that movements of the head set up movements in the endolymph of the canal, and these act as a stimulus to the nerve-endings around the hair-cells.

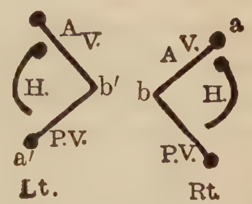


FIG. 211. — DIAGRAM SHOWING RELATIVE POSITION OF THE PLANES IN WHICH THE SEMICIRCULAR CANALS LIE, *Rt.*, right ear; *Lt.*, left ear; *A.V.*, anterior vertical canal; *P.V.*, posterior vertical canal; *H.*, horizontal canal; *a*, ampulla of *Rt.* anterior vertical canal; *a′*, ampulla of *Lt.* posterior vertical canal.

The canals are so arranged (Fig. 211) that any movement of the head causes an increase in the pressure of the endolymph in one ampulla, and a corresponding diminution in the ampulla of the parallel canal on the opposite side. Thus, a nodding of the head to the right would cause a flow of the endolymph from a to b in the right anterior vertical canal, but from b' to a' in the left posterior vertical canal. Hence the pressure upon the hairs is decreased in a, but increased in a'. Such stimulations of the sensory hairs are transmitted by the dendrites of the vestibular nerve, through the cell-bodies of the vestibular ganglion and the axones of the auditory nerve, to the pons Varolii and thence to the cerebellum. It is thought that the cerebellum is the centre in the brain which interprets and adjusts the impulses that arise from stimulation of the sensory nerves concerned with muscular sense. It is also the centre that interprets and adjusts impulses that arise from stimulation of the vestibular nerve-endings. From this it follows that the cerebellum controls equilibrium.

SIGHT

The visual apparatus consists of the eyeballs, the optic nerves, and the nerve centres in the brain. In addition to these essential organs, there are accessory organs which are necessary for the protection and functioning of the eyeball.

Accessory organs of the eye. — Under this heading we class: (1) eyebrows, (2) eyelids, (3) lacrimal apparatus, and (4) muscles of the eyeball.

Eyebrows. — The eyebrows are two thickened ridges of skin, covered with hairs. They are situated on the upper border of the orbits, and protect the eyes from too vivid light.

Eyelids. — The eyelids are two folds projecting from above and below in front of the eye. They are covered externally by the skin, and internally by a mucous membrane, the conjunctiva, which is reflected from them over the globe of the eye. They are composed for the most part of connective tissue, which is dense and fibrous under the conjunctiva, where it is known as the *tarsal cartilage*.

Arranged in a double or triple row at the margin of the lids are the *eyelashes;* those of the upper lid more numerous and longer than those of the lower. The upper lid is attached to a small muscle which is called the elevator of the upper lid (*levator palpebræ superioris*), and arranged as a sphincter around both lids is the *orbicularis palpebrarum* muscle, which closes the eyelids.

The slit between the edges of the lids is called the palpebral fissure. It is the size of this fissure which causes the appearance of large and small eyes, as the size of the lobe itself varies but little. The outer angle of this fissure is called the *external canthus;* the inner angle, the *internal canthus.*

The eyelids are obviously provided for the protection of the eye; movable shades which by their closure exclude light, particles of dust, and other injurious substances.

Tarsal glands (Meibomian glands). — Embedded in the tarsal cartilage of each eyelid is a row of elongated sebaceous glands, — the tarsal [1] glands, — the ducts of which open on the edge of

[1] By everting the eyelids, these glands may be seen through the conjunctiva lying in parallel rows.

the eyelid. The secretion of these glands prevents adhesion of the eyelids.

Lacrimal apparatus. — This apparatus consists of: (1) the lacrimal gland, (2) canaliculi, (3) lacrimal sac, and (4) nasal duct.

The **lacrimal gland** is a compound gland, and is lodged in a depression at the upper and outer angle of the orbit. It consists of two portions, an *upper* portion about the size and shape of an almond, and a *lower* portion consisting of a group of small glands arranged in a row. These two portions are only partially separated by a fibrous septum.

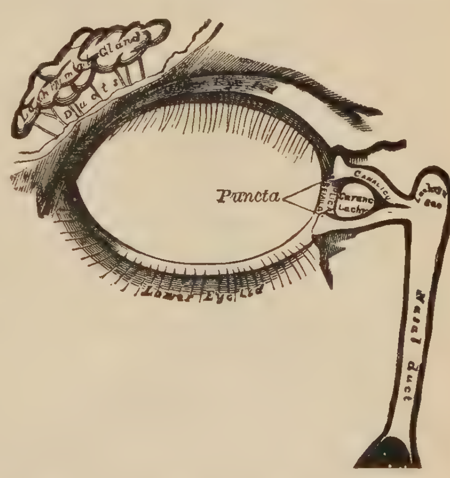


FIG. 212. — THE LACRIMAL APPARATUS. (Note that preference is given to the spelling "lacrimal" as found in text, instead of "lachrymal" as found on illustration.)

Seven to twelve minute ducts lead from the gland to the surface of the conjunctiva of the upper lid. The secretion (tears) is usually just enough to keep the eye moist, and after passing over the surface of the eyeball is sucked into two tiny *canaliculi* through the *punctæ* and is conveyed into the *lacrimal sac,* which is the upper dilated portion of the nasal duct.

The **nasal duct** is a membranous canal, about three-quarters of an inch (1.9 cm.) in length, which extends from the lacrimal sac to the nose, into which it opens, by a slightly expanded orifice.

The tears consist of water containing a little salt and albumin. They are ordinarily carried away as fast as formed, but under certain circumstances, as when the conjunctiva is irritated, or when painful emotions arise in the mind, the secretion of the lacrimal gland exceeds the drainage power of the nasal duct, and the fluid, accumulating between the lids, at length overflows and runs down the cheeks.

The conjunctiva. — The conjunctiva is the mucous membrane which lines the eyelids and is reflected over the front of the eyeball.

It is often considered part of the lacrimal apparatus as it secretes a fluid like that of the lacrimal gland.

Muscles of the eye. — For purposes of description the muscles of the eye are divided into two groups: (1) intrinsic, and (2) extrinsic. The intrinsic muscles are the ciliary muscle, and the muscles of the iris.[1] The extrinsic muscles are those which move the eyeball and include the four straight, or recti, and the two oblique. They have been described in Chapter VII.

Nerves of the eye. — The nerves which are supplied to the eye are: (1) the optic nerve, concerned with vision only; (2) the motor oculi nerve which controls the internal rectus, the superior rectus, the inferior rectus, and the inferior oblique muscles; (3) the pathetic nerve which controls the superior oblique muscle; (4) the abducens which controls the external rectus; and (5) the ophthalmic, which is a branch of the trifacial nerve, supplies general sensation.

The orbits. — The orbits are the bony cavities in which the eyeballs are contained.

Seven bones assist in the formation of each orbit, namely frontal, malar, maxilla, palate, ethmoid, sphenoid, and lacrimal. As three of these bones are mesial (frontal, ethmoid, and sphenoid) there are only eleven bones forming both orbits.

The orbit is shaped like a four-sided pyramid; the apex, directed backward and inward, is pierced by a large opening — the optic foramen — through which the optic nerve and the ophthalmic artery pass from the cranial cavity to the eye. A larger opening to the outer side of the optic foramen — the sphenoidal fissure — provides a passage for the ophthalmic vein and the nerves which carry impulses to and from the muscles, *i.e.*, the motor oculi, the pathetic, the abducens, and the ophthalmic. The base of the orbit, directed outward and forward, forms a strong, bony edge for protecting the eyeball from injury.

Each orbit averages about 2 inches (5 cm.) in depth, is lined with fibrous tissue, and contains a pad of fat, which serves as a support for the eyeball. A condition of emaciation is usually accompanied by sunken eyes, which results from the absorption of this fat, and the consequent sinking of the eyeballs in the orbits. Between the pad of fat and the eyeball is a serous sac — the

[1] See page 449.

capsule of Tenon — which envelops the eyeball from the optic nerve to the ciliary region and forms a socket in which the eyeball rotates. This sac secretes a lubricating fluid, the function of which is to prevent friction when the eyeball moves.

The eyeball. — The eyeball is spherical in shape, but its transverse diameter is less than the antero-posterior, so that it projects

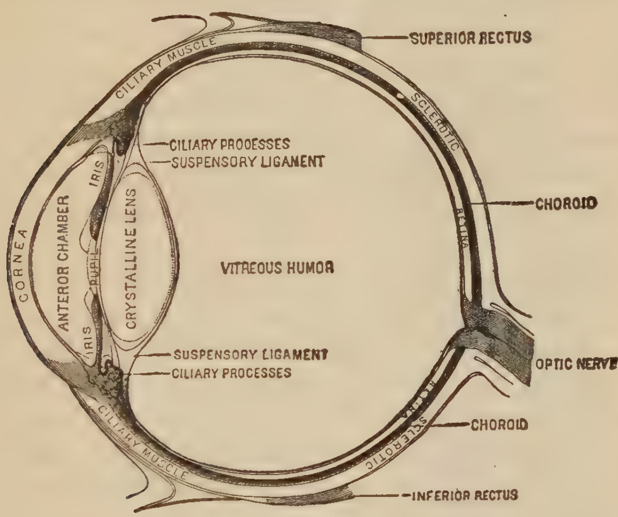


FIG. 213. — DIAGRAMMATIC SECTION OF THE EYE. (Flint.)

anteriorly, and looks as if a section of a smaller sphere had been engrafted on the front of it.

The eyeball is composed of three coats, or tunics, and contains three refracting media or humors. They are as follows: —

Tunics.—(1) Protective: (*a*) sclera; (*b*) cornea.
(2) Vascular: (*a*) choroid; (*b*) ciliary body; (*c*) iris.
(3) Visual: retina.

Refracting media. — (1) Aqueous.
(2) Crystalline lens and capsule.
(3) Vitreous.

Protective tunics. — (*a*) The *sclera*, or *white of the eye*, covers the posterior five-sixths of the eyeball. It is composed of a firm, unyielding, fibrous membrane, thicker behind than in front, and serves to protect the delicate structures contained within it, and maintain the shape of the eyeball. It is opaque; white and

smooth externally, and behind is pierced by the optic nerve. Internally it is stained brown where it comes in contact with the choroid coat. It is supplied with very few blood-vessels, and the existence of nerves in it is doubtful.

(*b*) The *cornea* covers the anterior sixth of the eyeball. It is directly continuous with the sclera, which, however, overlaps it slightly above and below, as a watch crystal is overlapped by the case into which it is fitted. The cornea, like the sclera, is composed of fibrous tissue, which is firm and unyielding, but, unlike the sclera, it has no color, and is perfectly transparent; it has been aptly termed the "window of the eye." The cornea is well supplied with nerves and lymph-spaces, but is destitute of blood-vessels, so that it is dependent on the lymph contained in the lymph-spaces for nutriment.

Vascular tunics. — (*a*) The *choroid*, or vascular coat of the eye, is a thin, dark brown membrane lining the inner surface of the sclera. It is composed of delicate connective tissue, the cells of which are large and filled with pigment, and it contains a close network of blood-vessels. The pigment cells and blood-vessels render this membrane dark and opaque, so that it darkens the chamber of the eye by preventing the reflection of light. It extends to within a short distance of the cornea.

(*b*) The *ciliary body* is located between the choroid and the iris, and contains the ciliary processes, and the ciliary muscle. Just behind the edge of the cornea, the choroid is folded inward and arranged in radiating folds, like a plaited ruffle, around the lens. There are about seventy of these folds, and they constitute the ciliary processes. They are well supplied with nerves and blood-vessels, and also support a muscle, the ciliary muscle. The fibres of this muscle arise from the sclera near the cornea, and extending backward are inserted into the outer surface of the ciliary processes and the choroid. The action of this muscle determines the position of the lens.

(*c*) The *iris* (*iris*, rainbow) is a colored, fibro-muscular curtain hanging in front of the lens and behind the cornea. It is attached at its circumference to the ciliary processes, with which it is practically continuous, and is also connected to the sclera and cornea at the point where they join one another. Except for this attachment at its circumference, it hangs free in the interior of the eye-

ball. In the middle of the iris is a circular hole, the *pupil*, through which light is admitted into the eye chamber. The iris, like the choroid, is composed of connective tissue containing a large number of pigment cells and numerous blood-vessels. It contains, in addition, two sets of muscles. One set is arranged like a sphincter with its fibres encircling the pupil, and is called the *contractor of the pupil*. The other set consists of fibres which radiate from the pupil to the outer circumference of the iris, and is called the *dilator of the pupil*. The action of these muscles is antagonistic.

The posterior surface of the iris is covered by a thick layer of pigment cells designed to darken the curtain and prevent the entrance of light. The anterior surface of the iris is also covered with pigment cells, and it is chiefly these latter which cause the beautiful colors seen in the iris. The different colors of eyes, however, are mainly due to the amount, and not to the color, of the pigment deposited.

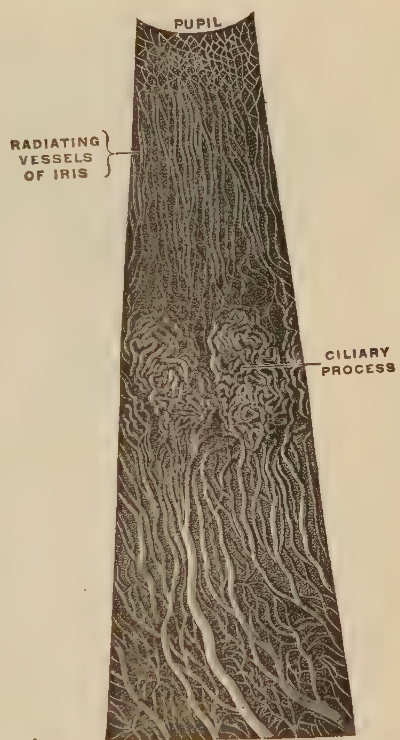


FIG. 214. — SEGMENT OF THE IRIS, CILIARY BODY, AND CHOROID. Viewed from the internal surface. (Gerrish.)

Function of the iris. — The function of the iris is to regulate the amount of light entering the eye, and thus assist in obtaining clear images. It is enabled to perform this function by the action of the muscles described above, as their contraction or relaxation determines the size of the pupil. When the eye is accommodated[1] for a near object, or stimulated by a bright light, the sphincter muscle contracts and diminishes the size of the pupil. When, on the other hand, the eye is accommodated for a distant object, or the light is dim, the dilator muscle contracts, and the pupil is pulled wider open.

[1] See page 453.

Visual tunic. — The *retina*, the innermost coat of the eyeball, is the most essential part of the organ of sight, since it is the only one directly sensitive to light. It is a transparent membrane of a grayish color that is formed by the spreading out or expansion of the optic nerve. It is situated between the inner surface of the choroid and the outer surface of the vitreous humor, and extends from the entrance of the optic nerve forward to the margin of the pupil.

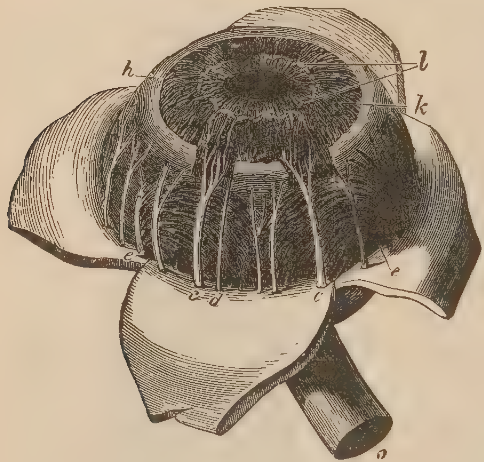


FIG. 215. — CHOROID MEMBRANE AND IRIS EXPOSED BY THE REMOVAL OF THE SCLERA AND CORNEA. Twice the natural size. *d*, one of the segments of the sclera thrown back; *l* and *k*, iris; *c*, ciliary nerves; *e*, one of the veins of the choroid. The ciliary muscle is crossed by the line from *k*, and should be represented as radiating. (Collins.)

The retina is usually described as consisting of eight layers and two limiting membranes; of these layers, three are most important: —

Eighth layer, or layer of nerve-fibres, is the internal layer.

Seventh layer is the layer of nerve-cells.

First layer, or layer of rods and cones, is the external layer. (See Summary, page 461.)

The fibres of the optic nerve, after piercing the sclera and choroid at the back of the eye, spread out and form the eighth, or innermost, layer of the retina. The fibres then pass, with more or less direct communications, peripherally through the other layers, until they may be said to terminate in the layer of rods and cones. Rays of light produce no effect upon the optic nerve without the intervention of the rods and cones, which act as end organs.

Blind spot. — The optic nerve pierces the eyeball not exactly at its most posterior point, but a little to the inner side. This point where the optic nerve enters is called the blind spot. There are no rods and cones at this spot, and rays of light falling upon it produce no sensation.

Macula lutea. — There is one point of the retina that is of great importance, and that is the macula lutea, or yellow spot. It is situated about one-twelfth inch (2.08 mm.) to the outer side of the exit of the optic nerve, and is the exact centre of the retina. In

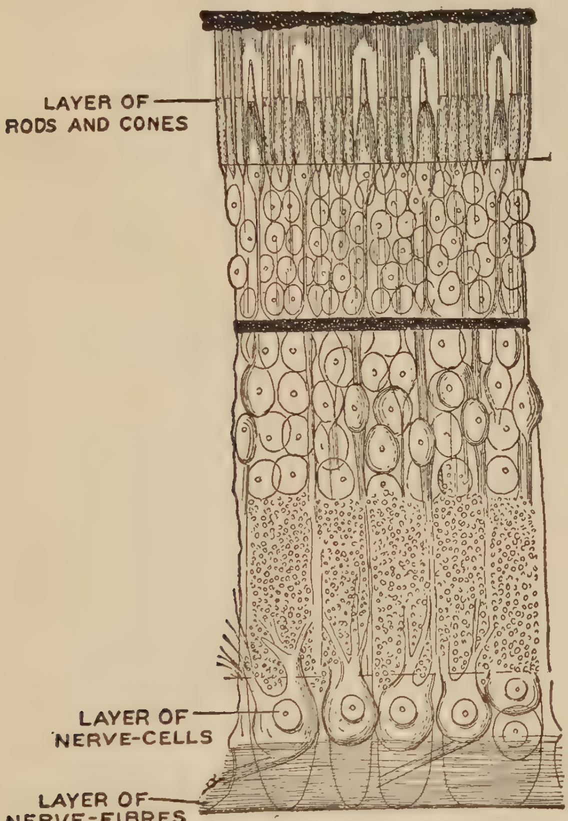


FIG. 216. — DIAGRAMMATIC SECTION OF THE HUMAN RETINA.

its centre is a tiny pit, — *fovea centralis,* — which is the centre of direct vision; that is, it is the part of the retina which is always turned towards the object looked at. From this point the sensitiveness of the retina grows less and less in all directions. At this point (fovea centralis) are found none of the fibres of the optic nerve, but a great increase in the number of cones, as well as in their size.

Perception of light. — It is commonly believed that all space is filled by ether, a medium so transparent and subtle that we are

not able to perceive it by any of our senses. Transverse vibrations or waves of this ether produce light, which enters the eye, falls upon the retina, and acts as a stimulus. It is supposed that waves of light cause chemical changes in the rods and cones which give rise to impulses that are carried by the optic nerve to the brain, and result in sight. Just how this is accomplished is not known, but the rods contain a kind of pigment which is called visual purple, and this as well as the pigment of the retina may function in these changes.

FIG. 217.—THE POSTERIOR HALF OF THE RETINA OF THE LEFT EYE VIEWED FROM BEFORE. Twice its natural size. *s*, cut edge of the sclera; *ch*, choroid; *r*, retina; in the interior at the middle, the macula lutea with the depression of the fovea centralis is represented by a slight oval shadow; toward the left side the light spot indicates the entrance of the optic nerve or blind spot. (Collins.)

The optic chiasm.—The fact that the two retinæ and the two eyeballs work in unison is largely due to the crossing of the nerve-fibres at the optic chiasm. The optic nerve from each eye passes backward through the optic foramen, and shortly after leaving the orbit the two nerves come together, and the fibres from the inner portion of each nerve cross. This is called the optic chiasm, and is really an incomplete crossing of fibres, as the outer fibres do not cross. (See Fig. 218.)

Refracting media.—(1) The *aqueous humor* is a colorless, transparent, watery fluid, which fills the aqueous chamber; the latter is the space bounded by the cornea in front and by the lens, suspensory ligament, and ciliary body behind. This space is partially divided by the iris into an anterior and posterior chamber.

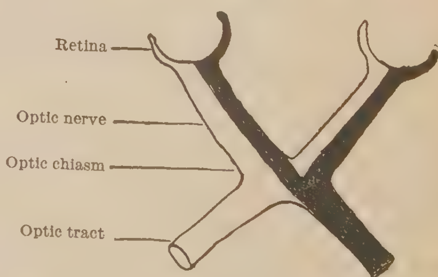


FIG. 218.—DIAGRAM OF OPTIC CHIASM.

(2) The *crystalline lens* is a transparent, refractive body, with

convex anterior and posterior surfaces placed directly behind the pupil, where it is retained in position by the counterbalancing pressure of the aqueous humor in front, and the vitreous body behind, and by its own suspensory ligament from the hyaloid membrane. It is a fibrous body, enclosed in an elastic, non-vascular capsule. The posterior surface is considerably more curved than the anterior, and the curvature of each varies with the period of life. In infancy, the lens is almost spherical; in the adult, of medium convexity; and in the aged, considerably flattened. Its refractive power is much greater than that of the aqueous or vitreous humor.

(3) The *vitreous humor*, a semi-fluid, gelatinous substance, fills the posterior four-fifths of the globe of the eyeball. It is enclosed in a thin membrane — the *hyaloid membrane*. This membrane is attached to the retina at the back of the eyeball, and furnishes a suspensory ligament to the lens. Elsewhere it is perfectly separable from its surroundings. The vitreous humor enclosed in this capsule distends the greater part of the sclera, supports the retina, which lies upon its surface, and preserves the spheroidal shape of the eyeball. Its refractive power, though slightly greater than that of the aqueous humor, does not differ much from that of water.

Refraction. — Refraction is the bending or deviation in the course of rays of light in passing obliquely from one transparent medium into another of different density. (See page 505.)

The refractive apparatus. — In order that our vision of objects looked at should be clear and distinct it is necessary that the rays of light entering the eye should be focussed on the retina. In the normal eye this is secured by the mechanism of accommodation (see next paragraph). The refractive apparatus consists of the aqueous humor, the crystalline lens, and the vitreous humor, which have just been described.

Accommodation. — Accommodation is the ability of the eye to adjust itself so that it can see objects at varying distances. The theory most generally accepted is that the ciliary muscle is the active agent in accommodation. When the eye is at rest or fixed upon distant objects the suspensory ligament exerts a tension upon the lens which keeps it flattened, particularly the anterior surface to which it is attached. When the eye becomes fixed on near objects, as in reading, sewing, etc., the ciliary muscle contracts

and draws forward the choroid coat, which in turn releases the tension of the suspensory ligament upon the lens, and allows the anterior surface to become more convex. The accommodation for near objects is an active condition and is always more or less fatiguing. On the contrary, the accommodation for distant objects is a passive condition, in consequence of which the eye rests for an indefinite time upon remote objects without fatigue.

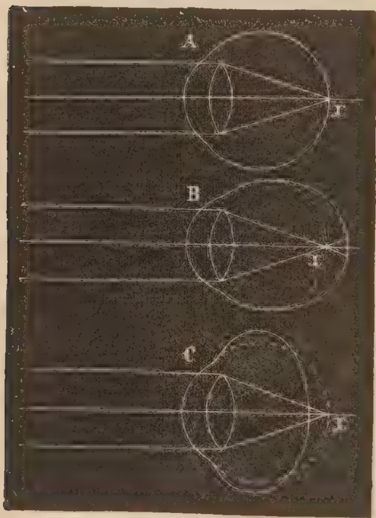


FIG. 219. — DIAGRAM ILLUSTRATING RAYS OF LIGHT CONVERGING IN (A) A NORMAL EYE, (B) A MYOPIC EYE, AND (C) A HYPERMETROPIC EYE.

Common conditions that affect accommodation. — The conditions that affect accommodation are: (1) hypermetropia, (2) myopia, (3) presbyopia, and (4) astigmatism.

Hypermetropia. — Hypermetropia or far-sightedness is a condition in which rays of light from near objects do not converge soon enough and are brought to a focus behind the retina. This is usually caused by a flattened condition of the lens or cornea, or an eyeball that is too shallow, and convex lenses[1] are used to concentrate and focus the rays more quickly.

Myopia. — Myopia or near-sightedness is a condition in which rays of light converge too soon, and are brought to a focus before reaching the retina. This is the opposite of hypermetropia and is caused by a cornea or lens that is too convex, or an eyeball of too great depth. To remedy this condition concave lenses are worn to disperse the rays and prevent their being focussed too soon.

Presbyopia. — Presbyopia is a defective condition of accommodation in which distant objects are seen distinctly, but near objects are indistinct. This is a physiological process which affects every eye sooner or later, and is not due to disease. It is said to be caused by a loss of the elasticity of the lens.

[1] See page 501.

Astigmatism. — Astigmatism is the condition in which the curvature of the cornea or lens is defective. An excess of curvature in the long axis of the cornea, as compared with that of its horizontal axis, is the more common defect. Glasses with curvatures the opposite of those of the eyes are used to correct this defect.

Inversion of images. — Due to refraction, light rays as they enter the eye cross each other and cause the image of external objects on the retina to be *inverted.* The question then arises, "Why is it that objects do not appear to us to be upside down?" This question is easily answered if we remember that our actual visual sensations take place in the brain, and that the projection of these sensations to the exterior is a secondary act that has been learned from experience.

SUMMARY

- **Sense-organ**
  - Peripheral end organ or receptor.
  - Connecting neurones for conduction of nerve-impulses.
  - A centre in the nervous system for interpretation or linkage with motor nerves.

- **Sensation**
  - Perception through the sense-organs.
  - Interpreted in the brain.
  - **Classification**
    - 1. Internal or those in which the sensations are projected to the interior of the body.
      - Pain.
      - Sensations from semicircular canals and vestibule of the internal ear.
      - Hunger.
      - Thirst.
      - Sexual sense.
      - Muscular sense.
      - Fatigue.
      - Visceral sensations.
    - 2. External or those in which the sensations are projected to the exterior of body.
      - Pressure.
      - Temperature (heat and cold).
      - Taste.
      - Smell.
      - Hearing.
      - Sight.

Cutaneous Sensations

- Surface of skin is a mosaic of sensory spots which coincide with location of special end organs for pressure, cold, heat, or pain.
- **Classification**
  - Epicritic
    - 1. Fibres for light pressure.
    - 2. Fibres for small difference of temperature, *i.e.*, between 26° and 37° C.
    - Special characteristic of skin area.
  - Protopathic
    - 1. Fibres for pain.
    - 2. Fibres for heat above 37° C.
    - Fibres for cold below 26° C.
    - Sensibility low, localization poor.

Pain

- Much evidence to support the theory that for cutaneous pain there exists a special set of fibres with a specific energy for pain.
- Overstimulation of sensory nerves in viscera and other parts of the body cause pain.
- Referred Pain
  - Pain arising in viscera and referred to skin area supplied with sensory fibres from the same spinal segment that supplies organ in question.

Muscle Sense

1. End organs situated in tendons and between fibres of muscles.
2. Afferent fibres carry impulses to centres in brain.
3. Efferent fibres carry impulses from brain to muscle.

Hunger

- Presumably due to contractions of empty stomach, acting on nerves distributed to mucous membrane.
- In abnormal conditions contractions may be weak or fail to occur at all.

Thirst

- Presumably due to stimulation of nerves of pharynx by low water content in tissues.

Taste

- Sensory apparatus
  - 1. Taste-buds are end organs.
  - 2. Nerve-fibres of trifacial, facial, and glossopharyngeal nerves.
  - 3. Centre in brain.
- Solution of sapid substances must come in contact with taste-buds.
- Taste-buds are distributed over
  - Surface of tongue.
  - Soft palate and fauces.
  - Tonsils and pharynx.

Tongue
- Freely movable muscular organ.
- Attached to hyoid bone, epiglottis, and pillars of the fauces.
- Surface covered by papillæ
  - Circumvallate.
  - Fungiform.
  - Filiform.
- **Nerves**
  - Sensory
    - Lingual, branch of trifacial.
    - Chorda tympani, branch of the facial.
    - Glossopharyngeal.
  - Motor — Hypoglossal.
- **Sense of**
  - 1. Taste
  - 2. Temperature
  - 3. Pressure
  - 4. Pain
  - Are all well developed.

Smell
- Sensory apparatus
  - Olfactory nerve-endings.
  - Olfactory nerve-fibres.
  - Centre in brain — olfactory bulb.
- Odors
  - Minute particles of solid matter
  - Gases
  - Must be capable of solution in mucus.
- Olfactory nerve-endings found in lining of upper part of nose (smell).
- Branches of trigeminal nerve found in lining of lower part of nose (pressure).

Hearing
- Auditory apparatus
  - External ear.
  - Middle ear.
  - Internal ear.
  - Auditory nerve.
  - Centre in brain.
- Air-waves enter external auditory canal and cause vibrations of drum-membrane. The vibrations are conveyed to nerve-endings of organ of Corti, and thence by the auditory nerve to the brain.

EAR
- **External Ear**
  - Pinna, or auricle
    - **Structure** — Cartilaginous framework, some fatty and muscular tissue, covered with skin.
    - **Function** — Collects sound-waves and reflects them into the auditory canal.
  - Auditory canal
    - 1 in. long, partly cartilage, partly bone.
    - Closed internally by the drum-membrane — Membrana tympani.
    - Hairs directed outward.
    - Ceruminous glands secrete a yellow, pasty substance.

- **EAR**
  - **Middle Ear**
    - An irregular cavity in the temporal bone.
    - Five or six drops of water will fill it.
    - **Bones**
      - Malleus (hammer).
      - Incus (anvil).
      - Stapes (stirrup).
    - **Openings**
      - Fenestra ovalis — closed by a membrane and the stapes.
      - Fenestra rotunda — closed by a membrane.
      - Eustachian tube — connects with the pharynx; ventilates cavity.
  - **Internal Ear**
    - **Bony Labyrinth**
      - Vestibule — antechamber just inside of fenestra ovalis.
      - Semicircular canals
        - Three in number.
        - Open into vestibule.
      - Vestibular branch of auditory nerve distributed to vestibule and semicircular canals.
      - Cochlea
        - A spiral tube.
        - $2\frac{1}{2}$ turns around modiolus.
        - Fenestra rotunda.
        - Cochlear branch of the auditory nerve.
    - **Membranous Labyrinth**
      - Surrounded by perilymph.
      - Contains endolymph.
      - Lines the vestibule
        - Saccule.
        - Utricle.
      - Lines the semicircular canals.
      - Lines the cochlea, and here it is called the canalis cochlearis, or scala media.
      - Membrana basilaris is name given to membrane at base of canal.
      - Organ of Corti, name given to end organs of auditory nerve lodged on membrana basilaris.
    - **Auditory Nerve**
      - Cochlear — terminates in and around the cells of organ of Corti.
      - Vestibular — terminates in hair-cells of saccule, utricle, and ampulla.
- **Sense of Equilibrium**
  - Function of the vestibule and semicircular canals.
  - Lining membrane supplied with sensory hairs which connect with vestibular nerve.
  - Contains several small otoliths which float in the endolymph.
  - Flowing of the endolymph stimulates the sensory hairs; this is transmitted to the vestibular nerve, thence to auditory nerve, thence to brain.

- **Visual Apparatus**
  - Eye.
  - Optic nerve.
  - Centre in brain.
  - Accessory organs
    - Eyebrows.
    - Eyelids.
    - Lacrimal apparatus.
    - Muscles.

- **Accessory Organs**
  - **Eyebrows**
    - Thickened ridges of skin furnished with short, thick hairs.
    - Control to a limited extent amount of light admitted to eye.
  - **Eyelids**
    - Folds of connective tissue covered with skin, lined with mucous membrane (conjunctiva), which is also reflected over the eyeball.
    - Provided with lashes.
    - Closed by orbicularis palpebrarum muscle.
    - Upper lid raised by levator palpebræ superioris.
    - Slit between lids called palpebral fissure.
    - Inner angle of slit called internal canthus.
    - Outer angle of slit called external canthus.
    - Function is protection. Serve as shades.
    - Tarsal glands are a row of glands embedded in tarsal cartilage of each lid.
  - **Lacrimal apparatus**
    - Lacrimal gland — in the upper and outer part of the orbit. Secretes tears.
    - Ducts — 7 to 12 lead from gland to conjunctiva.
    - Canaliculi — 2 canals $\frac{1}{4}$ to $\frac{1}{3}$ in. long, begin at punctæ and open into lacrimal sac.
    - Lacrimal sac — upper dilated portion of the nasal duct.
    - Nasal duct — canal $\frac{3}{4}$ in. long, extends from lacrimal sac to the nose.
    - **Tears**
      - Secretion constant.
      - Moisten the eyeball and help to moisten inspired air.
      - Consist of
        - Water.
        - Salt.
        - Albumin.
      - Carried off by nasal duct.
  - **Muscles**
    - **Extrinsic**
      - Superior rectus.
      - Inferior rectus.
      - Internal rectus.
      - External rectus.
      - Superior oblique.
      - Inferior oblique.
    - **Intrinsic**
      - Ciliary muscle
        - Determines the position of the lens.
      - Muscles of iris
        - Contractor of pupil.
        - Dilator of pupil.

Nerves of Eye
- 1. Optic nerve concerned with vision only.
- 2. Motor oculi controls
  - Internal rectus muscle.
  - Superior rectus muscle.
  - Inferior rectus muscle.
  - Inferior oblique muscle.
- 3. Pathetic controls the superior oblique muscle.
- 4. Abducens controls the external rectus muscle.
- 5. Ophthalmic.

Orbit
- Bony cavity formed by seven bones
  - Frontal.
  - Malar.
  - Maxilla.
  - Palate.
  - Ethmoid.
  - Sphenoid.
  - Lacrimal.
- Lined by fibrous tissue.
- Contains pad of fat — supports eyeball.
- Capsule of Tenon — prevents friction when eyeball moves.
- Shaped like four-sided pyramid
  - Apex directed backward.
  - Base directed forward.
- **Optic foramen** — opening for passage of optic nerve and ophthalmic artery.
- **Sphenoidal fissure** — opening for passage of ophthalmic vein and motor oculi, pathetic and abducens nerves.

Eyeball
- Spherical in shape, but it projects anteriorly.
- **Tunics**
  - 1. Protective — sclera and cornea.
  - 2. Vascular — choroid, ciliary body and iris.
  - 3. Visual — retina.
- **Media**
  - 1. Aqueous.
  - 2. Crystalline lens and capsule.
  - 3. Vitreous.

Protective Tunics
- **Sclera**
  - Tough, fibrous, opaque.
  - Covers posterior $\frac{5}{6}$ of eyeball.
  - Stained brown internally.
- **Cornea**
  - Fibrous, transparent — covers anterior of eyeball.
  - Well supplied with nerves.

- **Vascular Tunics**
  - **Choroid**
    - Vascular coat, lines the sclera.
    - Composed of connective tissue cells filled with pigment.
  - **Ciliary Body**
    - Terminates in front by the ciliary processes.
    - Ciliary processes 70 to 80 parallel folds of the choroid, rising gradually from behind and forming a plaited zone between the choroid and iris.
    - Support ciliary muscle — action of this muscle determines the position of the lens.
  - **Iris**
    - A circular curtain. Central perforation — pupil.
    - Pupil contracted by circular muscle-fibres.
    - Pupil dilated by radial muscle-fibres.
    - Contains pigment — amount of which determines color of the eyes.
    - Hangs free except for attachment at circumference to the ciliary processes and choroid.
    - **Function** — Regulates amount of light entering eye.

- **Visual Tunic or Retina**
  - Visual layer — transparent membrane of nervous and connective tissue situated between the choroid and vitreous humor. Formed by the spreading out of optic nerve.
  - Has eight layers and two membranes. Counting from the choroid inward as follows: —
  - Pigment layer, usually described as a membrane.
    1. Layer of rods and cones (perceptive layer) — external layer.
    2. Limitans externa.
    3. External granules.
    4. External molecular.
    5. Internal granules.
    6. Internal molecular.
    7. Ganglion or nerve-cells.
    8. Optic nerve-fibres — innermost layer.
  - Membrana limitans interna.
  - **Blind Spot**
    - Entrance of optic nerve.
    - There are no rods and cones.
    - Totally insensitive to light.
  - **Macula Lutea**
    - $\frac{1}{12}$ in. outside the blind spot.
    - Central pit — fovea centralis — is the centre of direct vision.
  - Vibrations of ether enter eye, strike on rods and cones, thence sensation is carried to the visual centre in the brain.

Refractive Apparatus
- **Aqueous**
  - Aqueous chamber is between cornea in front, and lens, suspensory ligament, and ciliary body behind. Aqueous humor is a colorless, transparent, watery fluid.
- **Crystalline lens**
  - Fibrous body enclosed in an elastic capsule.
  - Double convex in shape. Situated behind the pupil.
  - Held in position by counterbalancing of the aqueous and vitreous humors and the suspensory ligament.
- **Vitreous**
  - Semi-fluid, gelatinous substance.
  - Fills the posterior four-fifths of the globe of the eyeball, and is enclosed in the hyaloid membrane. Distends the sclera and supports the retina.

Refraction — Bending or deviation in the course of rays of light, in passing obliquely from one transparent medium into another of different density.

Accommodation — Ability of the eye to adjust itself so that it can see objects at varying distances.

Conditions that affect Accommodation
- **Hypermetropia**
  - Far-sightedness.
  - **Cause** — Rays of light do not converge soon enough.
- **Myopia . .**
  - Near-sightedness.
  - **Cause** — Rays of light converge too soon.
- **Presbyopia .**
  - Defective condition of accommodation in which distant objects are seen distinctly, but near objects are indistinct.
- **Astigmatism**
  - Condition in which the curvature of the cornea or lens is defective.

CHAPTER XXI

THE ORGANS OF GENERATION: PHYSIOLOGY OF REPRODUCTION

Female generative organs. — The female generative organs are divided into an internal and an external group. The internal are contained within the true pelvis, and the external are grouped under the name of vulva or pudendum.

INTERNAL GENERATIVE ORGANS

The internal generative organs comprise the following structures: —

(1) **Ovaries**, two glandular organs in which the ova are formed.

(2) **Fallopian** [uterine] tubes, two canals through which the ova reach the uterine cavity.

(3) **Uterus**, a hollow, pear-shaped organ, which receives the ovum.

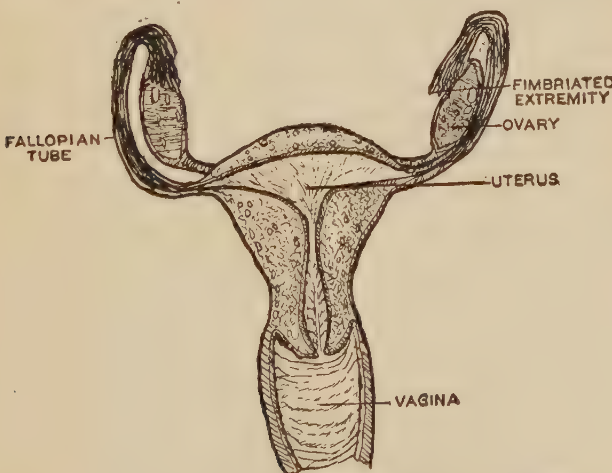


Fig. 220. — Uterus, Ovaries, and Fallopian Tubes.

(4) **Vagina**, a canal extending from the uterus to the vulva.

Ovaries. — The ovaries are two almond-shaped, glandular bodies, situated one on each side of the uterus, in the posterior fold

of the broad ligament, behind and below the Fallopian tubes. Each ovary is attached at its inner end to the uterus by a short ligament, — the ligament of the ovary, — and at its outer end to the Fallopian tube by one of the fringe-like processes of the fimbriated extremity. The ovaries each measure about one and a half inches (3.8 cm.) in length, three-fourths of an inch (1.9 cm.) in width, and one-third of an inch (8.5 mm.) in thickness, and weigh from one to two drachms (3.7 to 7.5 gms.).

Function. — The function of the ovaries is to produce, develop and mature the ova, and to discharge them when fully formed. In addition, the ovary furnishes an internal secretion, which is picked up by the blood.

Structure. — If the substance of an ovary be minutely examined it is found to consist of: (1) a stroma or bed composed of white and yellow fibrous tissue, blood-vessels, lymphatics, and nerves, (2) Graafian follicles, and (3) a covering of columnar epithelial cells, called germinal epithelium, which is continuous with the peritoneum.

Graafian (vesicular) follicles. — The Graafian follicles are sacs or vesicles which contain the ova and are embedded in the meshes of the stroma.

Each follicle consists of: (1) an outer coat of fibrous tissue that is derived from the stroma, and connected with it by a plexus of blood-vessels, and (2) an inner layer of nucleated cells. With the exception of the smallest vesicles each one is filled with fluid, and suspended in this fluid is an *ovum* surrounded by a mass of cells, called the *discus proligerus.*

At birth the ovaries are said to contain about 36,000 vesicles, each measuring from $\frac{1}{800}$ to $\frac{1}{100}$ of an inch in diameter, but only a small number of these ever develop, as the great majority shrink and disappear. At the time of puberty the ovaries enlarge, become very vascular, and some of the follicles increase in size. As the follicles increase in size they approach the surface and begin to form small protuberances on the outside of the ovary. When fully matured the wall of the ovary and the wall of the follicle burst at the same point, and the contents of the follicle — the fluid, the ovum, and the surrounding cells — escape. This process of development, maturation, and rupture of a follicle is known as ovulation, and continues at regular intervals from puberty to the menopause.

The corpus luteum. — After the rupture of a follicle, and the escape of the ovum, the walls collapse and the cavity becomes filled with blood which forms a clot. Later this clot becomes surrounded by cells containing a yellow pigment, which gives the follicle a yellow color, and hence it is known as the corpus luteum. The size and duration of the corpus luteum is dependent on whether pregnancy occurs or not. If pregnancy does not occur the corpus luteum increases in size for two or three weeks and then is absorbed. If pregnancy does occur the corpus luteum increases in size during the first few months, and does not show retrogressive changes until about the sixth month. Opinions differ regarding the physiological importance of the corpus luteum. Some physiologists regard it as a protective mechanism by means of which the cavity resulting from the rupture of the follicle is filled with a tissue which can be easily absorbed. Others attribute to the corpus luteum secretory functions of the most important character in connection with menstruation, the implantation of the fertilized ovum and its subsequent growth.

Fallopian tubes. — The Fallopian tubes or oviducts are two in number, one on each side, and pass from the upper angles of the uterus in a somewhat tortuous course between the folds and along the upper margin of the broad ligament, towards the sides of the pelvis. They are about four inches (10 cm.) long, and at the point of attachment to the uterus are very narrow, but gradually increase in size so that the distal end is larger. The margin of the distal end is surrounded by a number of fringe-like processes called *fimbriæ*. One of these fimbriæ is attached to the ovary. The uterine opening of the tube is minute, and will only admit a fine bristle; the abdominal opening is comparatively much larger.

The Fallopian tube consists of three coats: —

(1) The external, or **serous**, coat is derived from the peritoneum.

(2) The middle, or **muscular**, coat has two layers: one a layer of longitudinal cells and the other of circular cells.

(3) The internal, or **mucous**, coat is arranged in longitudinal folds and covered with ciliated epithelium. It is continuous at the inner end with the mucous lining of the uterus, and at the distal end with the serous lining of the abdominal cavity. This is the only place in the body where a mucous and serous lining are continuous with one another.

Function. — The function of the Fallopian tubes is to convey the ova from the ovaries to the uterus. Just how the ovum, after its discharge into the abdominal cavity, reaches the Fallopian tube is not known. It is thought that the movement of the cilia on the fimbriæ and in the tubes produces a current which draws the ovum into the tube. After the ovum enters the tube it is carried to the uterus by the peristaltic action of the tube and the movement of the cilia. It is considered probable that many of the ova discharged from the ovaries remain in the abdominal cavity, because of failure to reach the tubes. These ova disintegrate, are absorbed, and carried away by the blood. Occasionally such an ovum becomes impregnated and ectopic gestation results.

The uterus. — The uterus is a hollow, pear-shaped organ. In the virgin state it is situated in the pelvic cavity between the bladder and the rectum. Its length is estimated to be about three inches (7.5 cm.), its width two inches (5 cm.) at the upper part, and its thickness one inch (2.5 cm.). During pregnancy the uterus becomes enormously enlarged, attains the length of a foot (30 cm.) or more, extends into the umbilical region, and measures about eight to ten inches (20 to 25 cm.) in width. After parturition the uterus returns to almost its original size, but is always larger than before pregnancy. After the menopause, the uterus becomes smaller and atrophies.

Divisions. — For purposes of description the uterus is divided into three parts: the fundus, body, and neck.

The *fundus* is the convex part above the entrance of the tubes.

The *body* is the part between the fundus and the neck.

The *cervix* or neck is the lower constricted part and extends from the body of the uterus into the vagina.

The cavity of the uterus is small because of the great thickness of its walls; that part within the body is triangular in shape (▽), and has three openings, one at each upper angle, communicating with the Fallopian tubes, and one, the internal orifice, opening into the cavity of the cervix below. The cavity of the cervix, which is, of course, continuous with the cavity in the body, is constricted above, where it opens into the body by means of the internal orifice (internal os), and below, where it opens into the vagina by means of the external orifice (external os). Between these two openings the canal of the cervix is somewhat enlarged.

Structure. — The walls of the uterus are thick and consist of three coats: —

(1) An external **serous** coat derived from the peritoneum. It covers all of the uterus, and the posterior surface of the cervix, but not the anterior surface.

(2) A middle **muscular** coat which forms the bulk of the uterine walls. It consists of layers of plain muscular tissue intermixed with blood-vessels, lymphatics, and nerves. The arrangement of the muscles is very complex, as they run circularly, longitudinally, spirally, and cross and interlace in every direction.

(3) An internal **mucous** membrane, which is continuous with that lining the vagina and Fallopian tubes. It is highly vascular, provided with numerous mucous glands, and is covered with ciliated epithelium.

Blood supply of uterus. — The uterus is abundantly supplied with blood-vessels. The blood reaches the uterus by means of the uterine arteries from the internal iliacs, and the ovarian arteries from the aorta. Where the neck joins the body of the uterus, the arteries from both sides are united by a branch vessel, called the circumflex artery. If this branch is cut during a surgical operation, or a tear of the neck during parturition extends so far as to sever it, the hemorrhage is very profuse. The arteries are remarkable for their tortuous course and frequent anastomoses. The veins are of large size, and correspond in their behavior to the arteries.

Position of the uterus. — The uterus is not firmly attached or adherent to any part of the skeleton. It is, as it were, suspended in the pelvic cavity by ligaments. A full bladder pushes it backward; a distended rectum, forward. It alters its position, by gravity, or with change of posture. During gestation it rises into the abdominal cavity.

The fundus of the uterus is inclined forward, and the external orifice is directed downward and backward. (See Fig. 221.) *Anteversion* is the condition where the fundus turns too far forward. *Retroversion* is the condition where the fundus inclines backward. A bend may exist where the neck joins the body, and if the body is bent forward, it is described as *anteflexion;* if bent backward, *retroflexion.*

posterior walls being in contact. The muscular coat increases during pregnancy, and the mucous coat, because of the transverse folds, or rugæ, allow of dilatation of the canal during labor and birth.

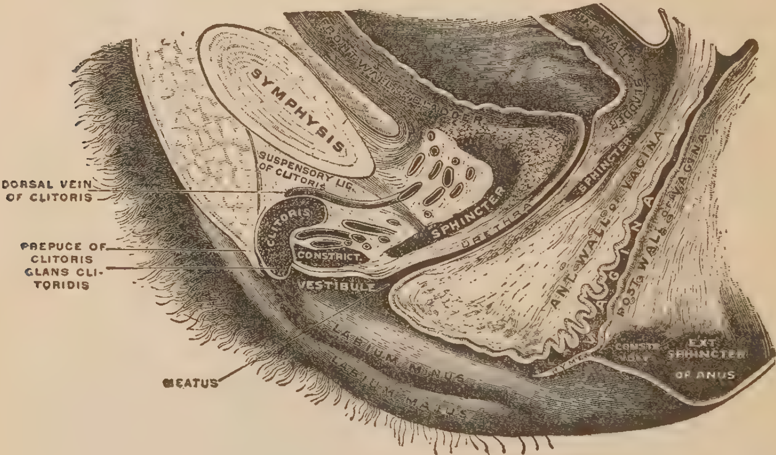


FIG. 222. — SAGITTAL SECTION OF THE VAGINA AND NEIGHBORING PARTS. (Gerrish.)

THE EXTERNAL ORGANS

The external organs of generation are grouped under the name of vulva or pudendum and include the following: —

1. Mons Veneris
2. Labia Majora
3. Labia Minora
4. The Clitoris
5. The Hymen
6. Glands { Vulvo-vaginal, Urethral

Mons Veneris. — The mons Veneris is an eminence situated in front of the pubic bones. It consists of areolar, adipose, and fibrous tissue covered with skin and after puberty with hair.

Labia majora. — The labia majora are two longitudinal folds of skin containing adipose and connective tissue. They are continuous with the mons Veneris in front, and extend to within an inch (25 mm.) of the anus behind.

Labia minora. — The labia minora are two longitudinal folds of modified epithelium situated between the labia majora. They are joined anteriorly in the hood or prepuce of the clitoris, and extend downward and backward for about one and one-half inches (3.8 cm.).

The clitoris. — The clitoris is a small body situated at the apex of the triangle formed by the junction of the labia minora. It contains many vessels and nerves and is almost completely covered by the hood or prepuce.

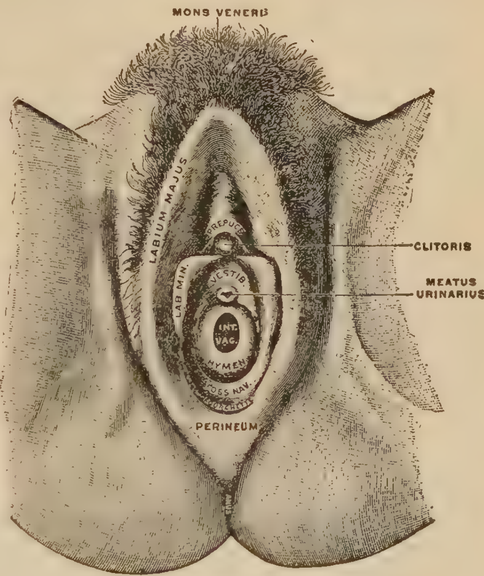


FIG. 223. — VULVA OF A VIRGIN. The labia have been widely separated. Foss. Nav., fossa navicularis; Int. Vag., introitus vaginæ; Lab. Min., labium minus; Vestib., vestibule. (Gerrish.)

The hymen. — The hymen is a fold of mucous membrane which surrounds the lower part of the vagina and renders the orifice smaller. It is quite elastic and may remain intact even after child-birth. Occasionally it extends entirely across and closes the orifice altogether. This condition is spoken of as imperforate hymen.

Glands. — In connection with the vulva are found: —

(1) Vulvo-vaginal glands or glands of Bartholin.

(2) Urethral glands.

The **vulvo-vaginal** are two round, or oval, glands, situated on either side of the vagina. Their ducts open into the vulval canal one on either side, in the groove between the hymen and labia minora. Their secretion lubricates the vulval canal.

The **urethral** glands are found chiefly beneath the walls and floor of the urethra. They secrete mucus.

Perineum. — The perineum bounds the external outlet of the pelvis and constitutes the floor of the genital canal. It consists of bands of muscular tissue strengthened and held together with fascia and covered with skin. An important part of the perineum is the triangular portion between the vagina and rectum. It is distensible and stretches to a remarkable extent during labor. Nevertheless it is frequently torn, and when the tear is of any

extent, and is not repaired, the vagina and uterus lose the support afforded by it, and various abnormal conditions follow.

PHYSIOLOGY OF THE FEMALE GENERATIVE ORGANS

Functions. — The functions of the female generative organs are: (1) the formation and development of the ovum, (2) the retention and sustenance of the fecundated ovum until it develops into a mature fœtus ready to live outside the body, and (3) the expulsion of the fœtus.

Puberty. — Puberty is the period at which the sexual organs become matured and functional and the girl develops into a woman. The event is not accomplished at once, but extends over considerable time. The girl undergoes a gradual change in figure, the hips broaden, the breasts develop, and for the first time a menstrual flow is noticed. At first the menstrual periods are scanty and irregular, but after a few months they settle down to the characteristic rate and duration. In temperate climates the age at which girls usually attain puberty is about fourteen years. In southern countries it is somewhat earlier, and in the arctic regions, a year or two later. However, no fixed rule can be given, as the time of arrival at puberty varies with every individual, depending on race, temperament, hygiene, and general surroundings.

The period of puberty during which the physical changes are occurring, is known as the *period of adolescence.*

Ovulation. — Ovulation includes the process of the development and maturation of the follicle and its ovum, and the rupture of the follicle.

The commonly accepted theory is that about or shortly before the age of puberty, the Graafian follicles begin to discharge their ova, and this process continues until the menopause. The frequency with which well-developed ova are discharged is the subject of much dispute. The most conservative view is that there is one mature ovum discharged for each menstrual epoch.

Menstruation. — Menstruation consists of the periodical discharge of bloody fluid from the uterine cavity. When once established it occurs on the average every twenty-eight days from the time of puberty to the menopause, with the exception of the period

of pregnancy and lactation. The average duration is from four to five days and the amount of blood lost is from four to six ounces (120 to 180 cc.). The menstrual fluid consists of mucus, epithelial cells, and blood. Some authorities are of the opinion that the mucous membrane of the uterus is normally shed during this process, others do not share this opinion.

The menopause or climacteric. — By menopause or climacteric is meant the physiological cessation of the menstrual flow, and the end of the period during which the Graafian follicles develop in the ovaries, and consequently the end of the child-bearing period. It is marked by atrophy of the breasts, uterus, tubes, and ovaries. The age of menopause varies as does the age of puberty; in general, we may say the earlier the puberty the earlier the menopause, and *vice versa.* In temperate climates the average period for the arrival of the menopause is at the age of forty-five years.

Changes in the generative organs in connection with menstruation. — At the beginning of menstruation there is a general congestion of the generative organs, including the breasts, accompanied by more or less discomfort and even pain. The mucous membrane of the uterus undergoes the following changes: (1) some days before the process there is marked hypertrophy and congestion of the mucous membrane, (2) during menstruation there is capillary hemorrhage and the epithelium of the mucous membrane may be cast off, (3) during the week following menstruation a new epithelium is formed and the mucous membrane returns to its normal size, (4) a period of rest extends to the next period of congestion.

Connection between ovulation and menstruation. — Whether ovulation depends upon menstruation or menstruation upon ovulation, or whether either has any connection with the other, is a matter of lengthy controversy. At the present time the generally accepted view is that menstruation is dependent upon the ovaries, and that their influence is exerted through the medium of the blood. It is thought that an internal secretion is formed in the ovaries; some physiologists think by the cells of the corpus luteum. This secretion is carried to the uterus by the blood and is responsible for the hypertrophy and congestion that precedes menstruation. So far it has not been possible to decide whether the internal secretion is entirely responsible for menstruation, or whether it is partly due to a power inherent in the uterine muscle.

The fact that operations for the removal of the ovaries are followed by atrophy of the uterus and cessation of menstruation, supports the theory that the ovaries are in some way responsible for menstruation.

Purpose of menstruation. — The purpose of the hypertrophy and congestion of the uterus is thought to be nature's way of preparing the uterine walls for the reception of the ovum should it become fertilized.

Mammary glands. — The two mammary glands, or breasts, may be considered as accessory organs of generation.

Function. — The function of the mammary glands is to secrete the milk which is needed for the nourishment of the young infant.

Location. — Each breast covers a nearly circular space in front of the pectoral muscles, extending from the second to the sixth rib, and from the sternum to the border of the arm-pit.

Structure. — The breasts are convex in shape, are covered externally by skin, and about the centre of the convexity a papilla projects, which is called the nipple. The nipple contains the openings of the milk ducts, and is surrounded by a small circular area of pink or dark colored skin, which is called the *areola*. They are compound glands, and are divided by connective tissue partitions into about twenty lobes, each of which possesses its own excretory duct, which as it approaches the top of the breast dilates and forms a small reservoir in which milk can be stored during the period when the gland is active. Each duct opens by a separate orifice upon the surface of the nipple. The lobes are subdivided, and the small lobes, or lobules, are made up of the terminal tubules of the duct, which lie in a mesh of fibrous areolar tissue containing considerable fat.

Blood-vessels and nerves. — The mammary glands are well supplied with blood brought to them by branches of the axillary, internal mammary, and intercostal arteries. The nerves are chiefly intercostal nerves.

Development of the mammary glands. — The increase in the size of the mammary glands at the time of puberty is due to an increased development of the connective tissue and fat. The glandular tissue remains undeveloped and does not function unless conception takes place. When conception occurs the glandular

tissue undergoes a process of gradual development that produces marked changes. The breasts become larger and harder, the veins on the surface become more noticeable, the areola becomes enlarged and darkened, the nipple becomes more prominent, and toward the end of pregnancy a fluid called colostrum can be

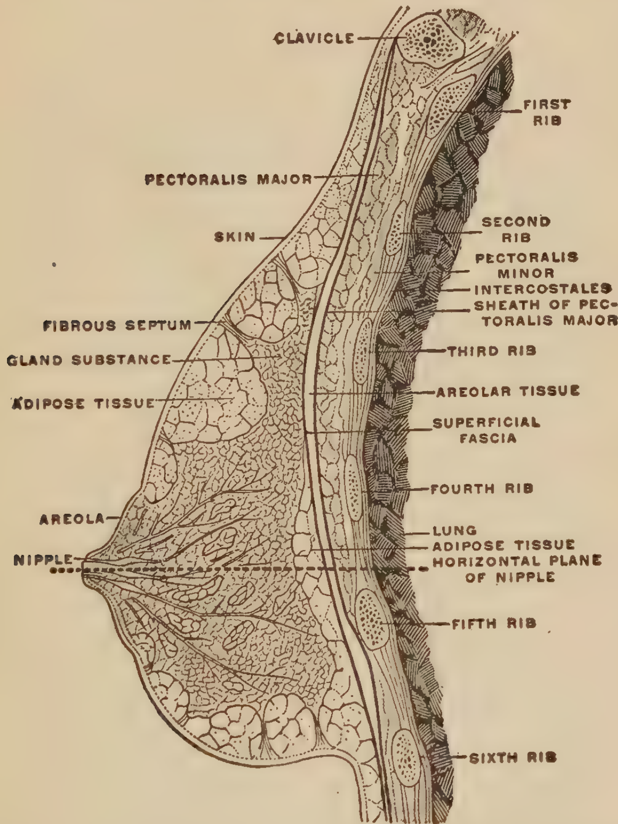


FIG. 224. — RIGHT BREAST IN SAGITTAL SECTION, INNER SURFACE OF OUTER SEGMENT. (Gerrish.)

squeezed from the orifice of the ducts. After delivery the amount of colostrum increases for a day or two, and then its composition changes to that of milk.

The primary development and later functioning of the mammary glands suggests an intimate connection between these glands and the uterus and ovaries. The present theory is that the increase in the size of the breasts at the time of puberty is influenced

by the internal secretion of the ovaries, for if the ovaries are removed before puberty, the breasts do not develop, or if the ovaries are removed after puberty, the breasts are apt to atrophy. The development of the glandular tissue that follows conception is thought to be due to some chemical substance, *e.g.*, a hormone, that results from the metabolism of the fœtus. The chemical nature of this substance is not known, but presumably it stimulates the development of the gland, and also prevents secretion, as active secretion does not commence until after delivery, and if conception occurs during the months of lactation, the character of the milk is changed and its secretion checked. The stimulus which causes the active secretion of milk is thought to result from the emptying of the milk ducts, because of the fact that when a woman does not nurse her infant, the secretion of milk is checked, and the breasts return to their usual size. The active secretion of milk is also influenced by the nervous system, and this influence is probably exerted through the vasomotor nerves which control the size of the blood-vessels, and consequently the amount of blood sent to the gland.

The secretion of milk. — The secretory portion of the mammary glands is the milk ducts, and these are lined with secreting cells. Some of the constituents of the milk, *i.e.*, water, salts, and sugar, are secreted by these cells from the blood, but it is thought that the cells themselves disintegrate and form the proteins and fat. The sugar contained in the milk is lactose, and the sugar of the blood is glucose, so if the first is derived from the second, some chemical change must take place either during or after secretion.

Colostrum and milk. — The secretion of the mammary glands during the first few days of lactation is called colostrum. It is a thin, yellowish fluid, composed of proteins, fat, sugar, salts, and water, but not in the same proportion as in milk. It also contains numerous cells containing large masses of fat. These are called colostrum corpuscles, and are secreting cells that are not completely broken down.

Human milk is specially adapted to the requirements of the infant and so differs in some respects from that of all other animals. Cow's milk is most frequently substituted for human milk and the relative composition of the two can be seen in the following table: —

	HUMAN (average)	COW'S (average)
Water	87–88%	87.00%
Proteins	2–3%	4.00%
Fat	3–4%	4.00%
Lactose	6–7%	4.30%
Salts	2–3%	0.70%

In substituting cow's milk for human milk the differences that must be taken into consideration are not only the different relative proportions, but also the following: (1) the difference in the proteins; the protein of human milk is one-third caseinogen, and two-thirds lactalbumin, and that of cow's milk is five-sixths caseinogen and one-sixth lactalbumin; (2) the difference in the curds formed in the stomach; human milk curdles in small flocculi, and cow's milk curdles in large heavy curds; and (3) the reaction of both human and cow's milk is amphoteric, but cow's milk is more nearly acid than human milk.

Male generative organs. — The male generative organs consist of the following structures: —

Testes, two glandular organs which produce the spermatozoa.
Vas Deferens.
Seminal Vesicles.
Ejaculatory Ducts.
The Spermatic Cords.
The Penis.
The Prostate Gland.
Cowper's Glands.

Testes. — The testes are two glandular organs which are suspended from the inguinal region by the spermatic cords, and are surrounded and supported by the scrotum. Each gland weighs from six to eight drachms (22 to 30 gms.) and consists of two portions: (1) the testicle proper, and (2) the epididymis.

(1) The *testicle proper* is ovoid in shape and covered exteriorly by fibrous tissue which sends incomplete partitions into the central portion of the gland, dividing it into communicating cavities. In these cavities are winding tubules which are surrounded by blood-vessels and held together by interstitial tissue. These

tubules inosculate in a sort of mesh (rete testis) and finally all unite in the epididymis.

(2) The *epididymis* is a long, narrow body which lies along the posterior portion of the testicle and consists of a tortuous tubule, which is lined with mucous membrane, and contains some muscular tissue in its walls. If unravelled it is found to be about twenty feet (5 metres) long. It connects the testicle proper with the vas deferens.

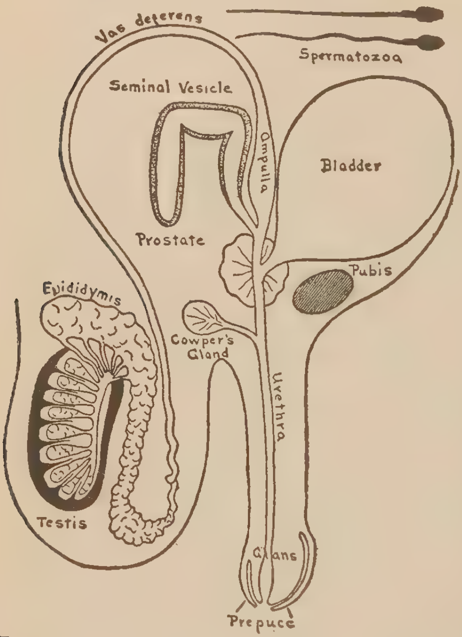


FIG. 225. — MALE SEXUAL APPARATUS. (Hall.)

Function. — The function of the testes is the production of spermatozoa. These spermatozoa are the essential part of the seminal fluid. The spermatozoa originate in the cells of the testes lining the tubules which compose the bulk of the testes. An internal secretion is also supposed to be formed here.

Descent of the testes. — In early fœtal life the testes are abdominal organs lying in front of and below the kidneys. During the process of growth they are drawn downward through the inguinal canal and shortly before birth are normally found in the scrotum. Sometimes, particularly in premature infants, a testis is found in the inguinal canal or even in the abdominal cavity; as a rule it soon descends and occupies its proper position; but occasionally it does not descend and an operation is necessary.

The Vas Deferens. — The vas deferens is a continuation of the epididymis, and is the excretory duct of the testicle. After a very devious course it joins the duct of the seminal vesicle at the base of the bladder. It consists of three coats, an external areolar, a middle muscular, and an internal mucous coat.

The Seminal Vesicles. — The seminal vesicles are two pouches which are placed each one on the outer side of each vas deferens, between the bladder and the rectum. They are pyramidal in form, with the broad ends directed backward and widely separated. The anterior portions converge, become narrowed, and unite on either side with the corresponding vas deferens to form the ejaculatory duct.

Function. — The seminal vesicles serve as a reservoir for the semen, to which they add a secretion of their own.

The Ejaculatory Ducts. — The ejaculatory ducts are two in number, one right and the other left. They are formed by the union of the seminal vesicle and vas deferens of each side. They run downward and converge as they descend, enter and pass between the lobes of the prostate gland and open into the floor of the prostatic portion of the urethra. Each has an external areolar, middle muscular, and internal mucous coat.

The scrotum. — The scrotum is a pouch which contains the testes and a part of each spermatic cord. It consists of a layer of skin, and the dartos. The skin is thick and dark, presents folds or rugæ, is furnished with sebaceous glands, and covered with short hairs. The dartos is a thin tunic of a reddish color consisting of muscular fibres and elastic tissue and containing numerous blood-vessels. It is continuous with the superficial fascia of the groin and perineum. It sends in a partition, which separates the two testes.

The Spermatic Cord. — The spermatic cord forms the pedicle of each testis and extends from the internal abdominal ring to the back of the testis. Each cord consists of the vas deferens, arteries, veins, lymphatics, nerves, the layers of fascia which cover the testis, and the remains of the peritoneal testicular process. These parts are connected together by areolar tissue.

The Penis. — The penis consists of three more or less cylindrical bodies of erectile [1] tissue enclosed in fibrous sheaths. The two corpora cavernosa lie above the corpus spongiosum, in which the urethra is contained. The glans penis is continuous with

[1] Erectile tissue is found in the clitoris, penis, and the nipples. The form, size, and consistency of this tissue changes according to the amount of blood contained in it. An increased amount of arterial blood causes swelling, and consequent pressure on, and occlusion of, the veins.

the corpus spongiosum. The covering of the penis is of loose skin, but over the glans penis, and lining the prepuce, it resembles mucous membrane. In this region there is an abundant subcutaneous nerve plexus and numerous Pacinian[1] corpuscles, so that it is possessed of acute sensibility.

The urethra extends from the bladder through the corpus spongiosum to the end of the penis. It is usually divided into three parts: (1) the prostatic urethra, (2) the membranous urethra, and (3) the penile or spongy portion. The length is usually given as eight inches (20 cm.), a large part of which lies inside the pelvis. It is lined with mucous membrane and furnished with numerous muscular fibres.

The Prostate. — The prostate gland is situated in front of the neck of the bladder and around the commencement of the urethra. It resembles a chestnut in form and consists of a dense fibrous capsule containing glandular and muscular tissue. The glandular tissue consists of tubules which communicate with the urethra by minute orifices.

Function. — The function of the prostate gland is to secrete the prostatic fluid, which is an essential element of the seminal fluid.

Cowper's glands. — These are two small bodies about the size of a pea situated one on each side, adjacent to, and opening into the membranous urethra. They secrete a fluid which goes to form part of the seminal fluid.

Puberty. — Puberty is the period at which the sexual organs become matured and functional, and the boy develops into a man. This occurs in the male about a year later than in the female, about fifteen years of age. At this time the "Adam's apple" develops, producing a marked change in the voice, the external genitals grow somewhat rapidly, hair grows on the face, pubes, axillæ, and other parts of the body, and seminal fluid begins to be secreted. At the same time sexual desires unknown before are experienced.

Semen. — The semen is a fluid derived from the various sexual glands in the male. The main elements in this fluid are the spermatozoa; the other constituents are derived from the seminal vesicles, prostate gland, and Cowper's glands.

[1] Pacinian corpuscles are specialized nerve-endings found in the genital organs of both sexes, also in the palms of the hands and the soles of the feet.

PHYSIOLOGY OF REPRODUCTION

Reproduction. — The purpose of reproduction is the continuation of the species, and is accomplished by means of the reproductive organs, whose importance is in their adaptation to produce another being. The reproduction of all living organisms is accomplished in two ways: —

(1) Asexually; (2) sexually.

(1) In the asexual type one individual divides into two or more, as is seen in the budding of plants and animals, also in the unicellular organisms when one organism constricts itself into two, either directly, or indirectly by mitosis, or divides itself up into a number of spores.

(2) In the sexual type, the individuals fuse either temporarily or permanently before cell division, or else they make sex cells (gametes) which fuse to form the new individual. In many of the lower organisms these sex cells are shed into the water and there unite. In most of the higher organisms the female sex cells or ova remain in the female organism, and the male sex cells are placed in the reproductive tract. In the human species the spermatozoa are placed in the vagina at the mouth of the uterus and swim upward through the uterus and the Fallopian tubes, in or near which union with the ova takes place.

Impregnation. — The term impregnation or fertilization is applied to the union of the spermatozoön or male cell with the ovum or female cell.

The ovum. — The ovum is a minute globular cell about $\frac{1}{125}$ inch (0.2 mm.) in diameter. (See Fig. 6 for cell structure.)

The spermatozoön. — The spermatozoön is much smaller than the ovum, being only $\frac{1}{500}$ inch (0.05 mm.) in length. It consists of an elliptical head, a rod-shaped middle piece, and a tail that gradually tapers. The head contains nuclear material and chromatin. There is an active vibratory motion of the tail which allows it quite free motion in the seminal fluid. Because of this free motion the spermatozoa are able, when deposited in the vagina, to travel upward into the uterus, and into the tubes even against the current produced by the cilia of the tubes.

Maturation of sex cells. — Before union the maturation of the sex cells takes place. In this process the number of chromosomes

is reduced to one-half the original number. Note that in Fig. 8 each chromosome is divided longitudinally into halves so that each new cell has the same number of chromosomes as the original cell. In maturation the division is such that each new cell has one-half the original number of chromosomes. Fusion or fertilization restores the normal number of chromosomes. Much of our theory of inheritance is based upon these chromosomes, and the fact that they are contributed to the individual, half by the sperm cell and half by the ovum.

Site of impregnation. — It is thought that impregnation takes place in the Fallopian tubes or near the wall of the ovaries. When the Graafian follicle ruptures and an ovum escapes into the abdominal cavity, the current produced by the cilia of the tubes is thought to draw it into the tube. Once in the tube the peristaltic action of the tube and the action of the cilia propel it slowly along to the uterus. If the ovum does not become impregnated it passes into the uterus and is cast off in the next menstrual flow. If, however, it is impregnated, segmentation or the process of cell division begins at once.

Segmentation. — The impregnated cell (zygote) rapidly divides into two, each of these two into other two, and so forth, until we have a number of cells where formerly there was one. At this stage the collection of cells is called the blastoderm. Gradually these cells which constitute the blastoderm become arranged in three layers, the outer called the ectoderm, an inner called the entoderm, and a middle layer called the mesoderm.[1] Later the organs are formed by the folding off of these tissues, and as the embryo grows it takes on the form of the adult.

The passage of the fertilized ovum through the tubes requires about eight days, and during this time many thousands of cells are formed and enclosed in a sac called the amnion. The collection of cells surrounded by the amnion is called an *embryo*. After entering the uterus the embryo attaches itself to the mucous membrane, in the upper portion, usually near the opening of the Fallopian tubes.

Changes in the uterine lining. — The preparation of the mucous membrane of the uterus for the reception of the impregnated ovum includes changes that are similar to those that precede menstrua-

[1] See page 28.

tion. The mucous membrane becomes softer, thicker, and highly congested. In this condition it is known as the *decidua vera,* and the point to which the ovum becomes attached and which later develops into the placenta is called *decidua serotina.*

Intrauterine growth. — During the period of intrauterine life growth takes place rapidly. From the union of the ovum, which is $\frac{1}{125}$ inch (0.2 mm.) in diameter, and the spermatozoön, which is much smaller, there is developed in two weeks' time an embryo which is about $\frac{1}{4}$ of an inch (6.25 mm.). At the end of four weeks it is about $\frac{1}{2}$ inch (12.5 mm.) long, and at four months it is called a fœtus, because it has the appearance of a human being, with well-developed eyes, fingers and toes separated, and the external genitals sufficiently formed to determine the sex. The usual duration of pregnancy is ten lunar or nine calendar months. At the end of six months the fœtus is sufficiently developed to live outside the mother's body, but it is frail and requires a great deal of care.

For further details on the subject of reproduction the student is referred to standard works on physiology and obstetrics.

SUMMARY

- **Female Generative Organs**
  - **Internal Organs**
    - Ovaries — two glandular organs in which the ova are formed.
    - Fallopian tubes — two canals through which the ova reach the uterine cavity.
    - Uterus — a hollow, pear-shaped organ which receives the ovum.
    - Vagina — a canal that extends from the uterus to the vulva.
  - **External Organs**
    - Mons Veneris — a cushion of areolar, fibrous and adipose tissue, in front of pubic bones, covered with skin and after puberty with hair.
    - Labia majora — two folds that extend from the mons Veneris to within an inch of the anus.
    - Labia minora — two folds situated between the labia majora.
    - Clitoris — small body, situated at apex of the triangle formed by junction of labia minora. Well supplied with nerves and blood-vessels.
    - Hymen — fold of mucous membrane that surrounds vaginal orifice.
    - **Glands**
      - Vulvo-vaginal — oval bodies situated on either side of the vagina.
      - Urethral — glands found chiefly beneath the walls and floor of urethra.

- **Ovaries**
  - Two almond-shaped glandular bodies.
  - Situated in posterior fold of broad ligament.
  - **Attached**
    - To uterus — by ligament of ovary.
    - To tubes — by fimbriæ.
  - **Size**
    - $1\frac{1}{2}$ inches long.
    - $\frac{3}{4}$ inch wide.
    - $\frac{1}{3}$ inch thick.
  - **Weight** — 1–2 drachms.
  - **Structure**
    - Stroma
      - Fibrous tissue.
      - Blood-vessels.
      - Lymphatics.
      - Nerves.
    - Graafian follicles
      1. Outer coat fibrous tissue.
      2. Inner layer of cells contain ovum.
    - Covering of germinal epithelium.
  - **Function**
    - Produce, develop, mature, and discharge ova.
    - Form an internal secretion.

- **Fallopian Tubes**
  - **Location**
    - Enclosed in layers of broad ligament.
    - Extend from upper angles of uterus to sides of pelvis.
  - **Divisions**
    1. Isthmus — or inner constricted portion near uterus.
    2. Ampulla — dilated portion which curves over ovary.
    3. Infundibulum — trumpet-shaped extremity — fimbriæ.
  - **Three Coats**
    1. External, or serous.
    2. Middle, or muscular.
    3. Internal, or mucous, arranged in longitudinal folds and covered with cilia.
  - **Function** — Convey ova to uterus.
- **Uterus**
  - Hollow, thick-walled organ, placed in pelvis between bladder and rectum.
  - **Divisions**
    - Fundus = rounded upper portion, above the entrance of the tubes.
    - Body = portion below fundus, above neck.
    - Cervix = lower and smaller portion which extends into vagina.
  - **Three Coats**
    - External, or serous, derived from peritoneum.
    - Muscular
      - Circular layer
      - Longitudinal layer
      - Spiral layer
      - Interlaced in every direction.
    - Mucous membrane, lines the uterus.
  - **Blood-vessels**
    - Uterine arteries from internal iliacs.
    - Ovarian arteries from aorta.
    - Remarkable for tortuous course and frequent anastomoses.
  - **Ligaments**
    - Broad, or lateral — two layers of serous membrane.
    - Round — two fibro-muscular cords.
    - Utero-sacral — two partly serous, partly muscular, ligaments.
    - Anterior — peritoneal floor of the utero-vesical pouch.
    - Recto-vaginal — peritoneal floor of the recto-vaginal pouch.
  - **Function** — To receive ovum, and if it becomes fertilized to retain it until developed and then to expel it.
- **Vagina**
  - **Canal** — Extends from uterus to vulva.
  - **Three Coats**
    - Outer coat is fibrous.
    - Middle coat is muscular.
    - Mucous coat, or lining, arranged in rugæ.
  - **Location** — Placed between urethra and rectum.

- **Physiology of Generative Organs**
  - **Function**
    - Formation and development of ovum.
    - Retention and sustenance of fecundated ovum.
  - **Puberty** — Age at which sexual organs become matured and functional. Girl changes to woman.
  - **Ovulation**
    - Process of development and maturation of follicle and ovum, and discharge of ovum.
  - **Menstruation**
    - A flow of blood from the uterus. Occurs on an average every twenty-eight days. Extends from puberty (14 years) to the menopause, or climacteric (about 45 years). This represents the child-bearing period of a woman's life.
    - Changes in connection with menstruation
      1. General congestion of generative organs, including breasts.
      2. Hypertrophy and congestion of mucous membrane of uterus.
      3. Capillary hemorrhage. Epithelium is cast off.
      4. Following menstruation a new epithelium is formed.
    - Connection between ovulation and menstruation
      - Probably dependent on internal secretion of ovaries, and possibly is aided by power inherent in uterine muscle.
    - **Purpose** — Nature's way of preparing uterine walls for reception of fertilized ovum.
  - **Menopause** — Physiological cessation of the menstrual flow.
- **Mammary Glands**
  - Accessory organs of generation.
  - **Function** — To secrete milk to nourish infant.
  - **Location**
    - Extend from second to sixth rib.
    - Sternum to arm-pit.
  - **Structure**
    - Outer surface convex — papilla projects from centre — called nipple — contains openings of milk ducts. Nipple surrounded by areola.
      1. Consists of connective tissue framework which divides the gland into about twenty lobes.
      2. Lobes are subdivided into lobules.
      3. Lobules are made up of terminal tubules of the duct.
      4. Each lobe possesses its own excretory duct, which is called lactiferous and is sacculated.
  - **Blood-vessels**
    - Axillary.
    - Internal mammary.
    - Intercostal.

Mammary Glands

- **Nerves** — Intercostal.
- **Development**
  - Primary development at time of puberty, probably due to internal secretion of ovaries.
  - Functional development follows conception, probably due to chemical substances that result from metabolism of fœtus. Active secretion stimulated by emptying milk ducts and influenced by nervous system.
- **Secretion of milk**
  - Water, Salts, Sugar — Secreted from blood.
  - Proteins, Fat — Formed by disintegration of cells lining lactiferous tubules.

Colostrum

- Thin yellowish fluid secreted during first few days of lactation.
- **Composition**

Proteins	5.71 per cent
Fat	2.04 per cent
Sugar	3.74 per cent
Salts	0.28 per cent
Water	88.23 per cent

Milk

- **Composition**

	Human	*Cow's*
Water	87–88%	87.00%
Proteins	2–3%	4.00%
Fat	3–4%	4.00%
Lactose	6–7%	4.30%
Salts	2–3%	0.70%

- **Differences**
  - Different relative proportions.
  - Difference in proteins
    - Human: Caseinogen $\frac{1}{3}$. Lactalbumin $\frac{2}{3}$.
    - Cow's: Caseinogen $\frac{5}{6}$. Lactalbumin $\frac{1}{6}$.
  - Difference in curds
    - Human — small flocculi.
    - Cow's — heavy curds.
  - Difference in reaction
    - Human — amphoteric.
    - Cow's — amphoteric, but more nearly acid.

Male Generative Organs

- Testes.
- Vas deferens.
- Seminal vesicles.
- Ejaculatory ducts.
- Spermatic cords.
- The penis.
- The prostate gland.
- Cowper's glands.

Testes
- Two glandular organs which produce the spermatozoa.
- **Structure**
  - **Testicle proper** — ovoid body covered by fibrous tissue. Central portion consists of irregular cavities filled with seminiferous tubules and blood-vessels.
  - **Epididymis** — tortuous tubule, forms long, narrow body which lies along posterior portion of testes.
- **Location**
  - In early fœtal life in abdomen below kidneys.
  - Before birth are normally drawn downward to scrotum, and are suspended by spermatic cord.
- **Function**
  - Production of spermatozoa.
  - Production of internal secretion.

Vas Deferens — Continuation of epididymis, and serves to connect the epididymis and the seminal vesicle of each side.

Seminal Vesicles
- Two pouches located between bladder and rectum on outer side of each vas deferens. Connect vas deferens with ejaculatory duct.
- **Function** — Serve as reservoirs for semen, to which they add a secretion of their own.

Ejaculatory Ducts
- Formed by union of seminal vesicles and vas deferens of each side.
- Run downward, converge, pass between lobes of prostate gland and open into the floor of the prostatic portion of the urethra.

Scrotum
- Pouch which contains testes and part of each spermatic cord.
- Structure
  - Covered with thick dark skin.
  - Dartos — reddish tunic under skin, consists of muscular and elastic tissue with numerous blood-vessels. Divided by septum into halves.

Spermatic Cords
- Consists of the vas deferens, arteries, veins, lymphatics, nerves, and layers of fasciæ connected by areolar tissue. Serve as pedicles for testes.
- Extends from the internal abdominal ring to the back of the testes.

Penis
- Consists of three cylindrical bodies of erectile tissue
  - Two corpora cavernosa, and one corpus spongiosum.
- Contains urethra which extends from bladder to the end of penis.
- Covered with skin and mucous membrane.

Urethra
- Extends from the bladder through the corpus spongiosum to the end of the penis. Length, 8 inches.
- Divisions
  - Prostatic portion.
  - Membranous portion.
  - Penile or spongy portion.
- Consists of
  - Mucous lining.
  - Numerous muscular fibres.

The Prostate
- Situated in front of the neck of the bladder and around the commencement of urethra.
- **Shape** — resembles chestnut.
- **Consists of**
  - Fibrous capsule containing glandular and muscular tissue. Glandular tissue consists of tubules which empty into urethra.
- **Function** — Secretion of prostatic fluid.

Cowper's Glands
- Located one on each side of membranous urethra, into which they empty. About the size of a pea.
- **Function** — Secretion of a fluid which forms part of seminal fluid.

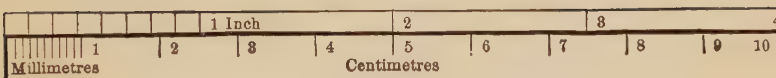
Puberty
- Age at which sexual organs become matured and functional.
- Boy changes to a man.

Semen
- Fluid derived from the various sexual glands in the male.
- Spermatozoa are the main elements.

Reproduction
- **Function** — Produce another being.
- Accomplished in two ways
  - Asexually
    1. Divide into two or more, *e.g.*, budding of plants and animals.
    2. Divide in two directly or by mitosis.
    3. Divide into spores.
  - Sexually
    1. Individuals fuse permanently or temporarily.
    2. Make sex cells (gametes).
       - (*a*) In lower organisms shed in water and unite.
       - (*b*) In higher organisms gamete retained by female, and male gamete is placed in reproductive tract of female.

- **Impregnation**
  - Union of spermatozoön and ovum.
  - Occurs in the Fallopian tubes or near the wall of the ovaries.
  - **Ovum** — Globular cell formed in ovaries $\frac{1}{125}$ inch in diameter.
  - **Spermatozoon**
    - A long, narrow cell formed in testes, $\frac{1}{500}$ of an inch in length.
    - Consists of
      - Elliptical head which contains nuclear material and chromatin.
      - Rod-shaped centre piece.
      - Tail.
    - Capable of independent motion in a fluid medium.
    - Function — to fertilize ovum.
- **Maturation of Sex Cells**
  - Reduction of chromosomes in each sex cell to one-half the original number.
  - Union of sex cells restores original number, hence one-half contributed by each sex.
  - Theory of inheritance based on chromosomes.
- **Development of Zygote**
  1. Impregnated cell divides into many cells. Collection called blastoderm.
  2. Blastoderm composed of
     - Entoderm.
     - Mesoderm.
     - Ectoderm.
  3. Tissues are folded off to form organs.
  4. In two weeks time embryo is $\frac{1}{4}$ inch long.
  5. In four weeks time embryo is $\frac{1}{2}$ inch long.
  6. At four months called a fœtus.

METRIC SYSTEM



The area of the figure within the heavy lines is that of a *square decimetre*. A cube, one of whose sides is this area, is a *cubic decimetre* or *litre*. A litre of water at the temperature of 4° C. weighs a *kilogramme*.

A litre is 2.11 pints or 33.81 ounces. A pint is 0.473 of a litre. (Liquid measure.)

A litre is 1.76 pint. A pint is 0.568 litre. (Dry measure.)

The smaller figures in dotted lines represent the areas of a square centimetre and of a square inch.

A cubic centimetre of water at 4° C. weighs a gramme.

Square Inch

Square Centimetre

1 Metre	=	39.370432 inches.
1 Decimetre	=	3.937043 inches.
1 Centimetre	=	.393704 inch.
1 Millimetre	=	.039370 inch.

1 Gramme	=	15.432 grains.
1 Decigramme	=	1.543 grains.
1 Centigramme	=	.154 grain.
1 Milligramme	=	.015 grain.
1 Dekagramme	=	154.323 grains.
1 Hektogramme	=	1543.235 grains.
1 Kilogramme	=	15432.350 grains.
1 Kilogramme	=	35.274 ounces.
1 Kilogramme	=	2.204 pounds.

Avoirdupois weights are used in weighing the organs of the body. One ounce avoirdupois = 28.35 grammes.

GLOSSARY

Abduc′tion. Drawn away from the middle line of the body.

Acromeg′aly. A disease characterized by an overgrowth of the extremities and the face as well as the soft parts.

Adduc′tion. Brought to or nearer the middle line.

Adre′nal. A small gland situated on the top of the kidneys. Same as supra-renal.

Af′ferent. *Bearing* or *carrying inwards*, as from the periphery to the centre.

Agglutina′tion. The mutual adhesion or clumping of foreign cells, and loss of motility in the case of motile bacteria, when suspended in fluid containing a suitable agglutinin.

Agglu′tinin. A substance occurring in blood plasma which produces agglutination by its action on the surface of foreign cells.

Ag′gregated. Formed by a collection of several bodies; crowded.

Ag′minated. Arranged in clusters, grouped together, as the agminated glands of Peyer in the small intestine.

Albu′mins. Thick, viscous substances containing nitrogen, that are soluble in water, dilute acids, dilute salines, and concentrated solutions of magnesium sulphate and sodium chloride. They are coagulated by heat and strong acids. Examples are: egg albumin and serum albumin of blood.

Albuminu′ria. Presence of *albumin* in the *urine*.

Alimen′tary. Pertaining to *aliment*, or food.

Alve′olus, pl. **Alve′oli.** Any little cell, pit, cavity, fossa, or socket. Socket of a tooth, or an air-cell.

Amito′sis. Fission or direct cell-division. Same as akinesis.

Amœ′ba. A single-celled organism, which is constantly *changing* its form by protrusions and withdrawals of its substance.

Amphoter′ic. Partly acid and partly alkaline in reaction; having the power of turning red litmus paper blue, and blue litmus paper red.

Ampul'la. The dilated part of a canal.

Anab'olism. The process by means of which simpler substances are *built up* into more complex substances.

Anastomo'sis. Communication of branches of vessels with one another.

An'tigens. Immunizing substances which, when introduced into the body of a susceptible animal, may produce specific antibodies.

An'trum. A cavity; applied especially to one in the upper maxillary bone, termed antrum of Highmore.

Aponeuro'sis. A flat wide band of fibrous tissue which is attached to a muscle.

Arach'noid. *Resembling a web.* The middle of the three membranes of the brain and spinal cord.

Arboriza'tion. A branching distribution of veinlets or of nerve-filaments, especially the branched terminal ramifications of a nerve-axone.

Are'olar. That form of connective tissue which fills the interstices between the various parts of the body; cellular.

Asex'ual. Having no distinction of sex; having no relation to sex. Asexual reproduction, reproduction without sexual intercourse.

Asphyx'ia. Suspended animation.

Assimila'tion. The conversion of food into living tissue.

At'las. The first cervical vertebra by which the head articulates with the spinal column, so called because it supports the head as Atlas was fabled to support the world on his shoulders.

At'rophy. Wasting of a part from lack of nutrition.

Au'ditory. Pertaining to the sense or organ of *hearing.*

Augmenta'tion. The act of increasing or making larger.

Aur'icle. A term applied to the *ear*-shaped cavities of the heart, also to the expanded portion of the external ear.

Automat'ic. Performed without the will; spontaneous. Same as autonomic.

Autonom'ic. Performed without the will; spontaneous. Same as automatic.

Auton'omy. Independence; the condition of having independent functions, limitations, and laws.

Ax'is. The second cervical or odontoid vertebra. Same as epistropheus.

Az'ygos. Without a fellow; hence, unpaired, single.

Bi'fid. Cleft in the middle.

Bifurca'tion. Division into two branches or forks.

Blas′toderm. The primitive membrane or layer of cells resulting from the subdivision of the germ.

Brach′ial. Belonging to the arm.

Brach′io-cephal′ic. Of or pertaining to both the upper arm and head; as the brachio-cephalic (innominate) artery and veins.

Bron′chiole. A small bronchial tube.

Bron′chus, pl. **Bron′chi.** One of the two main branches of the trachea.

Buc′cal. Pertaining to the mouth or *cheeks.*

Buc′cinator. The trumpeter's muscle. A thin, flat muscle that helps to form the wall of the cheek.

Bur′sal. Pertaining to *bursæ*, membranous sacs.

But′tock. The part at the back of the hip which, in man, forms one of the protuberances on which he sits.

Butyr′ic Acid. A colorless liquid having a strong rancid smell and acrid taste. C_3H_7COOH.

Cæ′cum. The first portion of the large intestine — a blind pouch.

Cal′culus, pl. **Cal′culi.** A stone.

Ca′lyx, pl. **Cal′yces.** Small *cup*-like membranous canals, which surround the papillæ of the kidney, and open into its pelvis.

Canalic′ulus, pl. **Canalic′uli.** A *small channel*, or vessel.

Can′cellated. A term used to describe the *lattice-work* texture of bone.

Ca′nine. Pointed like the tusks of a dog. Name given to the third tooth on each side of the jaw.

Can′thus. The angle formed by the junction of the eyelids, the internal being the greater, the external the lesser, canthus.

Car′dio-inhib′itory. An agent which restrains the heart's action.

Car′pus. The assemblage of bones forming the wrist.

Car′tilage. A solid but flexible material, forming a part of the joints, air-passages, nostrils, etc. *Gristle.*

Casein′ogen. The curd separated from milk by the addition of rennet, constituting the basis of cheese.

Cau′da Equi′na. A term applied to the termination of the spinal cord, which gives off a large number of nerves which, when unravelled, resemble a *horse's tail.*

Cau′date. Tail-like.

Centrif′ugal. Flying off or proceeding from the centre. Same as efferent.

Centrip′etal. Tending or moving toward the centre. Same as afferent. Opposed to centrifugal.

Cen′trosome. A peculiar rounded body lying near the nucleus of the cell. It is regarded as the dynamic element by means of which the machinery of cell division is organized.

Cephal′ic. Pertaining to the head.

Chi′asm. A crossing or decussation; especially that of the fibres of the optic nerve.

Choles′terin. A tasteless, inodorous, fatty substance found in small quantities in the protoplasm of all cells, especially in nerve-tissue, blood cells, and bile.

Chon′drin. A kind of gelatin obtained by boiling *cartilage.*

Chor′dæ Tendin′eæ. Tendinous cords.

Chor′da Tym′pani. The tympanic cord, a branch of the facial, or seventh cranial nerve, which traverses the tympanic cavity and joins the gustatory, or lingual, nerve.

Chro′mosome. Any one of the chromatin rods into which the spirem breaks during mitosis.

Cica′trix. The mark, or *scar*, left after the healing of a wound.

Cil′ia. Hair-like processes of certain cells.

Coalesce′. To grow together.

Cœ′liac. Pertaining to the abdominal *cavity.*

Collat′erals. Situated at the side; hence, also secondary.

Colum′næ Car′neæ. "Fleshy columns;" muscular projections in the ventricles of the heart.

Com′missure. A joining or uniting together. Something which joins together.

Congen′ital. Born with a person, existing from or before birth.

Contig′uous. Adjacent; near; in actual contact.

Convec′tion. A process of transfer or transmission, as of heat or electricity. The term "convection currents" is used in the text, and applies to currents of air produced by differences in temperature and density. Warm air expands, becomes less dense, and is forced upward by the cooler air, which is heavier, and sinks down. In this way convection currents are established.

Convolu′tions. The tortuous foldings of the external surface of the brain.

Co′rium. The deep layer of the skin; the derma.

Cor′onary. A term applied to vessels, ligaments, and nerves which encircle parts like a *crown*, as the coronary arteries of the heart.

Cor′pus Callo′sum. A name given to the white medullary *substance* joining the cerebral hemispheres.

Cor′pus Lu′teum. Yellow body, in the ovary taking the place of a Graafian follicle which has discharged its ovum.

Correla′tion. The interdependence of organs or functions; the reciprocal relations of organs.

Cor′tex. External or surface layer of an organ, such as the kidney or brain.

Cos′tal. Pertaining to the *ribs.*

Crena′ted. *Notched* on the edge.

Crib′riform. Perforated *like a sieve.*

Cru′ra Cer′ebri. Pillars of the *cerebrum.*

Crypt. A *secreting* cavity; a follicle, or glandular cavity.

Cul-de-sac. A tube or cavity closed at one end.

Cu′ticle. A term applied to the upper, or epidermal, layer of the *skin.*

Cu′tis Ve′ra. The true skin; that underneath the epidermal layer.

Cys′tic. Pertaining to a *cyst,* — a *bladder* or sac.

Decomposi′tion. (1) The separation of compound bodies into their constituent parts or principles. (2) Any ordinary process of decay, especially putrefaction.

Decussa′tion. To cross in the form of the letter X.

Degluti′tion. The act or power of swallowing.

Del′toid. Having a triangular shape; resembling the Greek letter Δ (*delta*).

Den′drite. A branching, protoplasmic process of a nerve-cell. Same as dendrone.

Denti′tion. (1) The process of cutting teeth. (2) The time during which teeth are being cut. (3) The kind, number, and arrangement of teeth proper to any animal.

Diabe′tes Insip′idus. A rare disease characterized by chronic polyuria, the urine having a low specific gravity, and being free from sugar.

Diabe′tes Melli′tus. A morbid chronic polyuria, associated with thirst and often with wasting, and with the presence of abnormal constituents (sugar) in the urine.

Dial′ysis. The passage through a permeable membrane of a substance in solution.

Diapede′sis. *Passing* of the red blood cells *through* vessel walls without rupture.

Dias′tole. The *dilatation* of the heart.

Diath′esis. A congenital condition of the system which renders it peculiarly liable to some diseases.

Dichot'omous. Divided into two. Pertaining to or consisting of a pair or pairs.

Dicrot'ic. Applied to the pulse, when there is a rebounding, like a double pulsation; having a double beat.

Diffu'sion. A property of certain bodies of dispersing or mixing themselves with the surrounding medium.

Dip'loë. The osseous tissue between the tables of the skull.

Dis'cus Prolig'erus or **germ disc.** A term applied to a mass of cells clinging to the ovum when it is set free from the ovary. More recent term is "ovarian mound."

Disintegra'tion. A breaking apart.

Distilla'tion. The act of distilling or of falling in drops. The operation of driving off gas or vapor from volatile liquids or solids, by heat in a retort or still, and the condensation of the products as far as possible by a cooler receiver.

Dor'sal. Pertaining to the *back*, or posterior part, of an organ.

Du'ra Ma'ter. The outer membrane of the brain and spinal cord. The "hard mother," called *dura* because of its great resistance, and *mater* because it is the guardian or protector of the brain.

Ec'toderm. The completed outer layer of cells, or outer blastodermic membrane. Same as epiblast.

Ectop'ic. Characterized as being *out of place.*

Ectop'ic Gesta'tion. The name given to pregnancy, when the fecundated ovum, instead of entering the uterus, either remains in a Fallopian tube, or the abdominal cavity.

Ef'ferent. *Bearing* or *carrying* outwards, as from the centre to the periphery.

Elemen'tary. Pertaining to or of the nature of an element or elements.

Elimina'tion. The act of *expelling* waste matters.

Em'bolus. A portion of a blood clot which has been formed in one of the larger vessels, and has afterward been forced into one of the smaller vessels, where it may act as a wedge.

Em'bryo. The ovum and product of conception up to the fourth month, when it becomes known as the fœtus.

Empir'ical. Relating to a knowledge of medicine obtained by experience alone.

Endocar'dium. Lining of the heart.

Endog'enous. Originating within the organism; not exogenous.

En′dolymph. The fluid in the membranous labyrinth of the ear.

Endos′teum. The lining membrane of the medullary cavity of a bone; the internal periosteum.

Endothe′lium. A term applied to single layers of flattened transparent cells, applied to each other at their edges and lining certain surfaces and cavities of the body. In contradistinction to epithelium.

En′siform. Shaped like a sword.

En′toderm. The completed inner layer of cells, or inner blastodermic membrane. Opposed to ectoderm. Same as hypoblast.

Epicra′nial. That which is upon the cranium or scalp.

Epider′mis. The outer layer of the skin.

Epigas′tric. Lying upon, distributed over, or pertaining to the abdomen or the stomach.

Epiglot′tis. The cartilage at the root of the tongue which forms a lid or cover for the aperture of the larynx.

Epimys′ium. The sheath of connective tissue surrounding an entire muscle.

Equilib′rium. That condition of rest which results when all the forces acting in a body are equally opposed. In physiology it signifies the harmonious action of the organs of the body, as in standing.

Evapora′tion. The act of resolving into vapor. In order to produce vapor, heat is necessary and, if not supplied, is taken from near objects. Thus the heat necessary for the evaporation of perspiration is taken from the body.

Excre′tion. The separation from the blood of waste particles; also the materials excreted.

Exog′enous. Developed outside of the body.

Exuda′tion. The passing out of any liquid through the walls or membranes of the vessels containing it.

Fal′ciform. Sickle-shaped.

Fallo′pian. A term applied to tubes and ligaments first pointed out by the anatomist *Fallopius*.

Fascic′ulus, pl. **Fascic′uli.** A bundle of close-set fibres.

Fau′ces. The constricted passage at the back of the mouth connecting the oral cavity and the pharynx.

Fecunda′tion. The act of making fruitful or prolific. Impregnation.

Fenes′tra. A window.

Fibril′la, pl. **Fibril′læ.** A *little fibre*.

Fi′brous. Containing or consisting of fibres. Having the character of fibres.

Fil′iform. Thread-like.

Fim′bria, pl. Fim′briæ. A border, or *fringe.*

Fis′sion. A *cleaving*, or breaking up into two parts.

Flat′ulence. Undue generation of gases in the stomach and intestines.

Fo′cus. A point at which the rays of light meet after being reflected or refracted. Point at which an image is formed.

Fœ′tus. The child in utero from the fourth month of pregnancy till birth.

Fol′licle. A *little bag;* a small gland.

Fontanelle′. A term applied to the membranous spaces existing between the cranial bones in the new-born infant. In these spaces the pulsation of the blood in the cranial arteries was imagined to rise and fall like the water in a fountain.

Fora′men, pl. Foram′ina. An opening, hole, or aperture.

Fos′sa, pl. Fos′sæ. A depression, or sinus; literally, a ditch.

Fo′vea Centra′lis. Central depression of the macula lutea. The point of most acute vision.

Fun′dus. The base or closed part of any organ which has an external opening.

Fun′giform. Having the *shape* of a *mushroom.*

Funic′ulus, pl. Funic′uli. A *little* cord, or bundle, of aggregated fibres.

Fu′siform. *Spindle-shaped.*

Gan′glion, pl. Gan′glia. A collection of nerve-cells in the course of a nerve, having the appearance of a knot.

Gen′erative. Pertaining to generation, or propagation. Connected with or resulting from the process of begetting.

Gen′itals. Pertaining to the organs of generation.

Gen′ito-u′rinary. Relating to the genital and urinary organs.

Gesta′tion. The act or condition of carrying young in the womb from conception to delivery. Pregnancy.

Glair′y. Like the *clear* white part of an egg.

Gle′noid. A name given to a shallow *cavity.*

Glob′ulins. Protein substances somewhat similar to the albumins, but differing in their solubility.

Glomer′ulus. A botanical term signifying a small, dense, roundish cluster: a term applied to the ball-like tuft of vessels in the cortical portion of the kidneys.

Glute'i, pl. of **Glute'us**. The muscles forming the *buttocks*.

Gly'cogenolysis. Conversion of glycogen into glucose.

Glycosu'ria. The presence of sugar in the urine.

Graaf'ian Fol'licles, or Ves'icles. A term applied to the sacs in the ovaries, which contain the ova, or cells.

Granula'tions. Grain-like, fleshy bodies that form on the surface of wounds and ulcers.

Gus'tatory. Belonging to the sense of *taste*.

Hæmoglo'bin. A compound protein found in the red cells of the blood; its molecule consists of a protein portion and of a pigment portion, the latter containing one atom of iron.

Hæmorrhoi'dal. Pertaining to hæmorrhoids, small tumors of the rectum, which frequently *bleed*.

Hem'atin. A proteid-free, pigmented constituent of hæmoglobin obtained by treating with acids.

Hemol'ysis. Destruction of the red blood-cells with a setting free of the hæmoglobin.

Hemophil'ia. A congenital, morbid condition, characterized by a tendency to bleed immoderately from any insignificant wound, or even spontaneously.

Hi'lum, sometimes written **Hi'lus**. It is the depression, usually on the concave side of a gland, where vessels, nerves, and ducts enter or leave.

Histol'ogy. That branch of anatomy which is concerned with the microscopic structure of the tissues of the body.

Homoge'neous. Of the *same kind* or quality throughout; uniform in nature, — the reverse of heterogeneous.

Homother'mous. Of equal temperature. Applied to animals whose temperature remains practically constant.

Hor'mone. A substance which is produced in one organ, and on being carried by the blood to another organ, stimulates this latter to functional activity.

Hy'aloid. The name given the membrane which encloses the vitreous humor of the eye.

Hydrother'apy. A mode of treating disease by the copious use of pure water, both internally and externally.

Hyperglycæ'mia. An abnormal amount of sugar in the blood.

Hyper'trophy. Excessive growth; thickening or enlargement of any part or organ.

Hypochon'driac. A term applied to the region of the abdomen *under* the *cartilages* of the false ribs.

Hypogas'tric. Situated below the stomach. Pertaining to the hypogastrium.

Hypoglos'sal. A name given to the motor nerve of the tongue.

Hypoph'ysis. The pituitary body of the brain which is lodged in the central depression of the sphenoid bone.

Il'eum. The *twisted* portion of the small intestine.

Il'ium, pl. **Il'ia.** The upper part of the os innominatum.

Immis'cible. Not capable of being mixed.

Inflamma'tion. A morbid condition characterized by pain, heat, redness, swelling, and usually loss of function.

Infundib'ulum, pl. **Infundib'ula.** A *funnel*-shaped canal.

Ingest'. Taking food into the stomach.

In'guinal. Pertaining to the *groin.*

Inhibi'tion. Restraint; the physiological arrest or suppression of any process, effected through nerves and special nerve centres.

Innom'inate. A name given an artery, a vein, and a bone.

Inocula'tion. The injection of virus into any part of the body, either as an operative procedure or by accident.

Inos'culate. To unite, to open into each other.

In'sulate. To isolate or separate from surroundings.

Integ'ument. The skin, or outer covering, of the body.

Intercel'lular. Lying *between cells.*

Intercos'tal. Situated or intervening between successive ribs of the same side of the body.

Interlob'ular. That which lies *between* the *lobules* of any organ.

In'terstice. The space which *stands between* things; spaces between parts.

Intersti'tial. Pertaining to or containing *interstices.*

Intes'tine. The part of the alimentary canal which is continuous with the lower end of the stomach; also called the bowels.

Intralob'ular. That which lies *within* the *lobules* of any organ.

I'ris. The colored membrane suspended behind the cornea of the eye.

Is'chium, pl. **Is'chii.** The lower portion of the os innominatum; that upon which the body is *supported* in a sitting posture.

Jeju'num. The part of the small intestine comprised between the duodenum and ileum.

Katab′olism. The process by means of which complex substances are rendered more simple and less complex. The opposite of anabolism.

Lacta′tion. The period of giving *milk.*

Lactif′erous. Bearing, or conveying milk, as a lactiferous duct.

Lacu′na, pl. **Lacu′næ.** A little *hollow space.*

Lambdoi′dal. Resembling the Greek letter **Λ.**

Lamel′la, pl. **Lamel′læ.** A thin plate, or layer.

Lam′ina. A thin plate; a germinal layer.

Laryn′goscope. The instrument by which the larynx may be examined in the living subject.

Lar′ynx. The upper part of the air-passage, between the trachea and the base of the tongue.

Latis′simus Dor′si. The *widest* muscle of the *back.*

Lens. A transparent substance, usually glass, bounded by two curved surfaces, or by one curved and one plain. There are two general classes of lenses: (1) concave, which are thinner at the centre than at the edges; and (2) convex, which are thicker at the centre than at the edges. (See page 454.)

Lob′ule. A *small lobe.*

Lum′bar. Pertaining to the *loins.*

Lu′men. The transverse section of a vessel or cavity.

Lym′phoid. Having *resemblance* to *lymph.*

Mac′ula Lu′tea. Yellow spot.

Malle′olus, pl. **Malle′oli.** A name given to the pointed projections formed by the bones of the leg at the ankle-joint.

Malpi′ghian Bodies (so called in honor of *Malpighi,* a celebrated Italian anatomist). A term applied to small bodies, or corpuscles, found in the kidney and spleen.

Ma′trix. The womb. Producing or containing substance.

Matura′tion. The process of bringing, or of coming to maturity.

Mea′tus. An opening leading to a canal, duct, or cavity.

Mediasti′num. The septum of the pleura which divides the cavity of the thorax into two parts.

Medul′la Oblonga′ta. That portion of the brain which lies within the skull, upon the basilar process of the occipital bone.

Meibo′mian. A term applied to the small glands between the conjunctiva and tarsal cartilages, discovered by *Meibomius.* More recent term is tarsal glands.

Mes'entery. A fold of peritoneum attaching some part of the intestine to the posterior wall of the abdomen.

Me'sial. Median, dividing into two symmetrical portions.

Mesoco'lon. A duplicature of the peritoneum covering the colon.

Metab'olism. The *changes* taking place in cells, whereby they become more complex and contain more force, or less complex and contain less force. The former is constructive metabolism, or anabolism; the latter, destructive metabolism, or katabolism.

Metacar'pus. The part of the hand comprised between the *wrist* and fingers.

Metatar'sus. That part of the foot comprised between the *instep* and toes.

Mito'sis. Processes of indirect cell-division. Same as karyokinesis.

Mi'tral. Resembling a mitre.

Mu'cin. The chief constituent of mucus.

Myocar'dium. The *muscular* structure of the *heart.*

My'osin. Chief protein substance of muscle.

Na'ris, pl. **Na'res.** A nostril.

Neurilem'ma. Nerve-sheath.

Neurog'lia. The supporting tissue of the nervous system, contains the glia cells.

Neu'rone. The nerve-cell, inclusive of all its processes.

Node. A lymphatic ganglion.

Nucle'olus, pl. **Nucle'oli.** A smaller nucleus within the nucleus.

Nu'cleus, pl. **Nu'clei.** A minute vesicle embedded in the cell protoplasm.

Nutri'tion. The processes by which the nourishment of the body is accomplished.

Odon'toid. Tooth-like.

Œde'ma. A *swelling* from effusion of serous fluid into the areolar tissue.

Or'bital. Pertaining to the *orbit,* the bony cavity in which the eyeball is suspended.

Or'gan. Any part of the body with a special function.

Or'ifice. An opening.

Ōs, pl. **Ō'ra.** A mouth.

Os, pl. **Os'sa.** A bone.

Oscilla'tion. Swinging backward and forward; vibration.

Os Cox'a, pl. **Os'sa Cox'æ.** The hip bone, or os innominatum.

Os'sa Innomina'ta, pl. of **Os Innomina'tum**. "Unnamed bones." The irregular *bones* of the pelvis, *unnamed* on account of their non-resemblance to any known object.

Os'seous. Consisting of or resembling bone.

Os'sicle. A small bone.

Os'teoblasts. The *germinal* cells deposited in the development of *bone*.

O'toliths. *Particles* of calcium carbonate and phosphate found in the internal *ear*.

O'vum, pl. **O'va**. The human germ-cell.

Pal'ate. The roof of the mouth, consisting of the hard and soft palate.

Pan'creas. A compound secreting gland; one of the accessory organs of nutrition. The sweetbread of animals.

Papil'læ, pl. of **Papil'la**. Minute eminences on various surfaces of the body.

Pari'etal. Pertaining to a *wall*.

Parturi'tion. The act of giving birth to young.

Pec'toral. Pertaining to the *breast*, or chest.

Ped'icle. A stalk.

Pedun'cle. A narrow part acting as a support.

Per'meable. Capable of being passed through; substances which allow the passage of fluids.

Perone'al. Pertaining to the *fibula;* a term applied to muscles, or vessels, in relation to the fibula.

Pe'trous. Having the hardness of *rock*.

Phalan'ges. A name given to the small bones forming the fingers and toes, because placed alongside one another like a *phalanx*.

Phar'ynx. The cavity forming the upper part of the gullet.

Phlebot'omy. The opening of a vein; venesection.

Phona'tion. Utterance of vocal sounds.

Phren'ic. Pertaining to the *diaphragm*.

Pi'a Ma'ter. The most internal of the three membranes of the brain.

Pig'ment. *Coloring* matter.

Pis'iform. Having the *form* of a *pea*. One of the carpal bones.

Placen'ta. A *flat*, circular, vascular body which forms the organ of nutrition and excretion for the fœtus in utero.

Plan'tar. Pertaining to the *sole of the foot*.

Plex'us. A *network* of nerves or veins.

Pneumogas'tric. Pertaining to the *lungs* and *stomach*.

Poi′kilother′mous. Changing the body temperature with the temperature of the surrounding medium; applied to cold-blooded animals, bacteria, and plants. The human fœtus is cold-blooded.

Polyu′ria. Excessive flow of watery urine.

Pons Varo′lii. "Bridge of Varo′lius." The square portion of medullary substance connecting the cerebrum, cerebellum, and medulla oblongata.

Poplite′al. The space *behind the knee-joint* is called the *popliteal* space.

Prismat′ic. Resembling a *prism*, which, in optics, is a solid, triangular-shaped glass body.

Prona′tion. The turning of the hand with the palm downward.

Prona′tor. The group of muscles which turn the hand palm downward.

Pseudopo′dium. A protrusion of the substance of an amœba or an amœboid cell, as in locomotion.

Psy′chical. Pertaining to the mind.

Pu′berty. Sexual maturity in the human race; the age at which reproduction becomes possible.

Pu′bis, pl. **Pu′bes.** The hairy region above the genitals, also used for os pubis, the portion of the os innominatum forming the front of the pelvis.

Pyrex′ia. Elevation of temperature; fever.

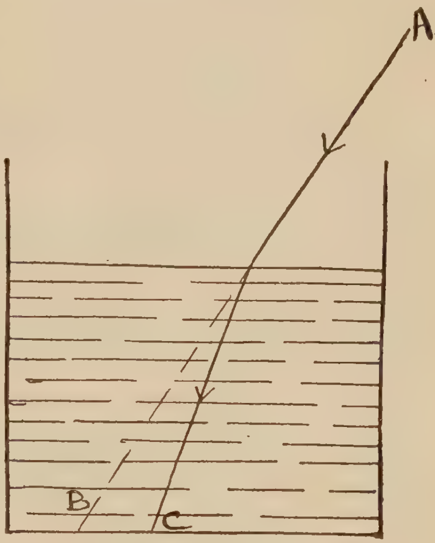
Radia′tion. The act of spreading outward from a central point. The diffusion of rays of light.

Râle. A rattling, bubbling sound attending the circulation of air in the lungs. Different from the murmur produced in health.

Rec′tus, pl. **Rec′ti.** Straight. A name given to muscles of the eye and abdomen.

Reflec′tion. The return of rays, beams, sound, or the like from a surface. Reflection of light is of two kinds, *regular* and *diffused*. When a beam of light enters a darkened room through a small opening and strikes a mirror, a reflected beam will be seen travelling along some definite path. This is called *regular reflection.* Should the light, however, fall on a piece of white paper, it would be reflected and scattered in all directions. This is called *diffused reflection*, and is caused by the inequalities of the reflecting surface. All rough surfaces, as well as dust and moisture in the atmosphere, serve to diffuse light. If this were not the case, it would be dark everywhere except in the direct path of light from some luminous body.

Refrac'tion. The bending or deviation in the course of rays of light in passing obliquely from one transparent medium into another of different density. Light waves travel with different velocities in mediums of different densities, the more dense the medium, the less the velocity. For instance, light will travel less rapidly in water than in air. For this reason where a ray of light in air strikes a body of water obliquely, it will be bent out of a straight line, as shown in the following diagram; the light ray *AC*, instead of following the straight line *AB*, is bent on striking the surface of the dense medium, thereby being bent from its direct path toward *C*.



Resil'iency. The act of leaping, or springing back; the act of rebounding.

Res'tiform. In anatomy denoting a part of the medulla oblongata, called the restiform body.

Retic'ular. Resembling a *small net.*

Ret'iform. Having the *form,* or structure, of a *net.*

Ret'ina. The most internal membrane of the eye; the expansion of the optic nerve.

Ru'gæ. A term applied to the folds, or *wrinkles,* in the mucous membrane, especially of the stomach and vagina.

Sag'ittal. Arrow-like.

Saliva'tion. An excessive secretion of saliva.

Saphe'nous. A name given to the two large superficial veins of the lower limbs.

Sap'id. Possessing savor or flavor.

Saponifica'tion. Conversion into soap.

Se'bum, or **Se'vum.** A fatty secretion resembling *suet,* which lubricates the surface of the skin.

Secre′tion. The process of separating from the blood some essential fluid, which fluid is also called a secretion.

Secre′togogue. An agent which stimulates secretion.

Segmenta′tion. The process of division of the fertilized ovum before differentiation into layers occurs.

Se′rum. The clear liquid which separates in the clotting of blood from the clot and blood cells.

Ses′amoid. *Resembling a grain of sesamum.* A term applied to the small bones situated in the substance of tendons, near certain joints.

Sig′moid. Curved *like the letter s.*

So′leus. A name given to a muscle shaped like the *sole* of a *shoe.*

Sphinc′ter. A circular muscle which contracts the aperture to which it is attached.

Splanch′nic. Of or pertaining to the viscera.

Squa′mous. *Scale-like.*

Sta′sis. Stagnation of the blood current.

Stim′ulus, pl. **Stim′uli.** Anything that excites to action.

Sto′ma, pl. **Sto′mata.** A *mouth;* a small opening.

Strat′ified. Formed or composed of *strata,* or layers.

Stri′ated. That which has *striæ,* furrows, or lines.

Stro′ma. The foundation or *bed* tissue of an organ.

Sty′loid. A long and slender process from the lower side of the temporal bone.

Sudorif′erous. A term applied to the glands secreting *sweat.*

Sul′cus. A fissure between two convolutions of the surface of the brain.

Supina′tion. The turning of the hand with the palm upward.

Su′pinators. The muscles which turn the hand with the palm upward.

Su′pra-or′bital. Above the orbit.

Su′ture. That which is *sewn together,* a seam; the seam uniting bones of the skull.

Synap′se. Interlacing of terminal arborization of nerves.

Sys′tole. The *contraction* of the heart.

Tac′tile. Relating to the sense of touch.

Tar′sus. The instep; also the cartilage of the eyelid.

Tem′poral. Pertaining to the temples; the name of an artery and of a bone.

Ten'do Achil'lis. "Tendon of Achilles." The *tendon* attached to the heel, so named because *Achilles* is supposed to have been held by the heel when his mother dipped him in the river Styx to render him invulnerable.

Ten'don. The white, fibrous cord, or band, by which a muscle is attached to a bone; a sinew.

Throm'bus. Name given to a clot formed in a blood-vessel.

Tibia'lis Ante'rior. The muscle situated at the *anterior* part of the *tibia.*

Tox'ic. Poisonous.

Trabec'ulæ. A term applied to prolongations of fibrous membranes which form septa, or partitions.

Transversa'lis. A term applied to a muscle which runs in a *transverse* direction.

Trape'zius. A name given to the two upper superficial muscles of the back, because together they resemble a *trapezium*, or diamond-shaped quadrangle.

Trap'ezoid. One of the bones of the wrist. The second one of the distal row on the radial or thumb side.

Tri'ceps. A term applied to a muscle having a triple origin, or *three heads.*

Tricus'pid. Having *three points.*

Trigem'inal. Threefold; triple; also relating to the fifth nerve.

Tu'bular. Having the form of a tube, or pipe.

Umbili'cus. A round cicatrix, or scar, in the median line of the abdomen.

Unicel'lular. Composed of a single cell.

Va'gus. Pneumogastric nerve.

Vas'cular. Relating to vessels; full of vessels.

Ver'miform. Worm-shaped.

Ver'nix Caseo'sa. The *fatty varnish* found on the new-born infant, which is secreted by the sebaceous glands of the skin.

Ver'tebra, pl. **Ver'tebræ.** The bones of the spine.

Vibra'tion. The act of moving rapidly to and fro.

Vil'lus, pl. **Vil'li.** The conical projections on the valvulæ conniventes, making the mucous membrane look shaggy.

Vit'reous. *Glass*-like. A name applied to the transparent, jelly-like substance which fills the back part of the eyeball behind the crystalline lens.

Vo′mer. The thin plate of bone shaped somewhat like a *ploughshare* which separates the nostrils.

Xi′phoid. Shaped like or resembling a sword, ensiform.

Zygomat′ic. Of or pertaining to the malar bone, or this bone and its connections. Constituting or entering into the formation of the zygome.

Zy′mogen. A mother substance or antecedent of an enzyme.

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